16-1. A wheel has an initial clockwise angular velocity of 10 rad/s and a constant angular acceleration of 3 rad/s^2. Determine the number of revolutions it must undergo to acquire a clockwise angular velocity of 15 rad/s. What time is required?

$$\omega^2 = \omega_0^2 + 2\alpha_c(\theta - \theta_0)$$

$$(15)^2 = (10)^2 + 2(3)(\theta - 0)$$

$$\theta = 20.83 \text{ rad} = 20.83\left(\frac{1}{2\pi}\right) = 3.32 \text{ rev.}$$ **Ans**

$$\omega = \omega_0 + \alpha_c t$$

$$15 = 10 + 3t$$

$$t = 1.67 \text{ s}$$ **Ans**

16-2. A flywheel has its angular speed increased uniformly from 15 rad/s to 60 rad/s in 80 s. If the diameter of the wheel is ~~2 ft~~, ~~determine the magnitudes of the~~ 1m normal and tangential components of acceleration of a point on the rim of the wheel when $t = 80$ s, and the total distance the point travels during the time period.

$$\omega = \omega_0 + \alpha_c t$$

$$60 = 15 + \alpha_c(80)$$

$$\alpha_c = 0.5625 \text{ rad/s}^2$$

0.5 0.281 m/s^2

$$a_t = \alpha r = (0.5625)(\cancel{1}) = \cancel{0.562 \text{ ft/s}^2}$$ **Ans**

0.5 1800 m/s^2

$$a_n = \omega^2 r = (60)^2(\cancel{1}) = \cancel{3600 \text{ ft/s}^2}$$ **Ans**

$$\omega^2 = \omega_0^2 + 2\alpha_c(\theta - \theta_0)$$

0.281

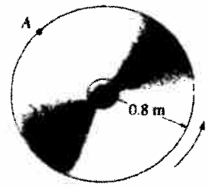
$$(60)^2 = (15)^2 + 2(\cancel{0.5625})(\theta - 0)$$

$$\theta = \cancel{3000 \text{ rad}}$$ 6000 rad

6000 × 0.5

$$s = \theta r = \cancel{3000(1)} = \cancel{3000 \text{ ft}}$$ 3000 m **Ans**

16-3. The angular velocity of the disk is defined by $\omega = (5t^2 + 2)$ rad/s, where t is in seconds. Determine the magnitudes of the velocity and acceleration of point A on the disk when $t = 0.5$ s.



$\omega = (5t^2 + 2)$ rad/s

$\alpha = \frac{d\omega}{dt} = 10t$

$t = 0.5$ s

$\omega = 3.25$ rad/s

$\alpha = 5$ rad/s^2

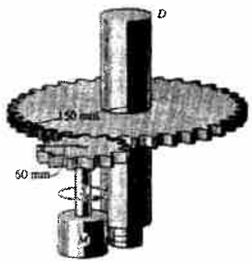
$v_A = \omega r = 3.25(0.8) = 2.60$ m/s **Ans**

$a_t = \alpha r = 5(0.8) = 4$ m/s^2

$a_n = \omega^2 r = (3.25)^2(0.8) = 8.45$ m/s^2

$a_A = \sqrt{(4)^2 + (8.45)^2} = 9.35$ m/s^2 **Ans**

***16-4.** The figure shows the internal gearing of a "spinner" used for drilling wells. With constant angular acceleration, the motor M rotates the shaft S to 100 rev/min in $t = 2$ s starting from rest. Determine the angular acceleration of the drill-pipe connection D and the number of revolutions it makes during the 2-s start up.



$\omega_M = 100$ rev/min(1min/60 s)(2π rad/1 rev) $= 10.472$ rad/s

$\omega = \omega_0 + \alpha_c t$

$10.472 = 0 + \alpha_c(2)$

$\alpha_M = 5.236$ rad/s^2

$\alpha_M r_M = \alpha_D r_D$

$(5.236)(60) = \alpha_D(150)$

$\alpha_D = 2.094 = 2.09$ rad/s^2 **Ans**

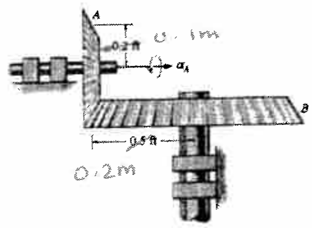
$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$

$\theta = 0 + 0 + \frac{1}{2}(2.094)(2)^2$

$\theta = 4.19$ rad $= 0.667$ rev **Ans**

4

16-~~5~~. If gear A starts from rest and has a constant angular acceleration of $\alpha_A = 2$ rad/s^2, determine the time needed for gear B to attain an angular velocity of $\omega_B = 50$ rad/s.



The point in contact with both gears has a speed of

$v_P = \omega_B r_B = 50(\cancel{0.5}\ 0.2) = \cancel{25\text{ ft/s}}$ 10 m/s

Thus,

$\omega_A = \frac{v_P}{r_A} = \frac{\cancel{25}\ 10}{\cancel{0.2}\ 0.1} = \cancel{125\text{ rad/s}}$ 100 rad/s

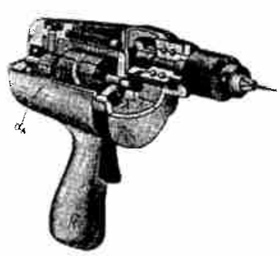
So that

$\omega = \omega_0 + \alpha_c t$

$\cancel{125}\ 100 = 0 + 2t$

$t = \cancel{62.5\text{ s}}$ **Ans** 50 s

16-6. If the armature A of the electric motor in the drill has a constant angular acceleration of $\alpha_A = 20\ \text{rad/s}^2$, determine its angular velocity and angular displacement when $t = 3$ s. The motor starts from rest.



$$\omega = \omega_0 + \alpha_c t$$

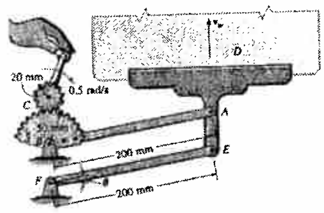
$$= 0 + 20(3) = 60\ \text{rad/s} \qquad \textbf{Ans}$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$$

$$= 0 + 0 + \frac{1}{2}(20)(3)^2$$

$$= 90\ \text{rad} \qquad \textbf{Ans}$$

16-7. The mechanism for a car window winder is shown in the figure. Here the handle turns the small cog C, which rotates the spur gear S, thereby rotating the fixed-connected lever AB which raises track D in which the window rests. The window is free to slide on the track. If the handle is wound at 0.5 rad/s, determine the speed of points A and E and the speed v_w of the window at the instant $\theta = 30°$.



$$v_C = \omega_C r_C = 0.5(0.02) = 0.01\ \text{m/s}$$

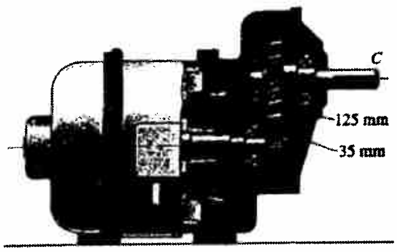
$$\omega_S = \frac{v_C}{r_S} = \frac{0.01}{0.05} = 0.2\ \text{rad/s}$$

$$v_A = v_E = \omega_S r_A = 0.2(0.2) = 0.04\ \text{m/s} = 40\ \text{mm/s} \qquad \textbf{Ans}$$

Points A and E move along circular paths. The vertical component closes the window.

$$v_w = 40\cos 30° = 34.6\ \text{mm/s} \qquad \textbf{Ans}$$

•16-8. The pinion gear A on the motor shaft is given a constant angular acceleration $\alpha = 3\ \text{rad/s}^2$. If the gears A and B have the dimensions shown, determine the angular velocity and angular displacement of the output shaft C, when $t = 2$ s starting from rest. The shaft is fixed to B and turns with it.



$$\omega = \omega_0 + \alpha_c t$$

$$\omega_A = 0 + 3(2) = 6 \text{ rad/s}$$

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$$

$$\theta_A = 0 + 0 + \frac{1}{2}(3)(2)^2$$

$$\theta_A = 6 \text{ rad}$$

$$\omega_A r_A = \omega_B r_B$$

$$6(35) = \omega_B(125)$$

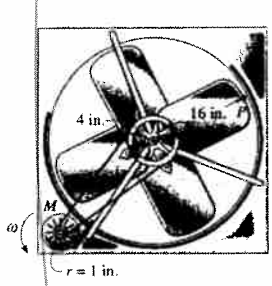
$$\omega_C = \omega_B = 1.68 \text{ rad/s} \qquad \textbf{Ans}$$

$$\theta_A r_A = \theta_B r_B$$

$$6(35) = \theta_B(125)$$

$$\theta_C = \theta_B = 1.68 \text{ rad} \qquad \textbf{Ans}$$

16-9. The motor M begins rotating at $\omega = 4(1 - e^{-t})$ rad/s, where t is in seconds. If the pulleys and fan have the radii shown, determine the magnitudes of the velocity and acceleration of point P on the fan blade when $t = 0.5$ s. Also, what is the maximum speed of this point?



$$\omega_m = 4(1 - e^{-t})$$

$$\alpha_m = \frac{d\omega}{dt} = 4e^{-t}$$

When $t = 0.5$ s

$$\omega_m = 1.57388 \text{ rad/s}$$

$$\alpha_m = 2.4261 \text{ rad/s}$$

$$\omega_m r_m = \omega_p r_p$$

$$1.57388(1) = \omega_p(4)$$

$$\omega_p = 0.39347 \text{ rad/s}$$

$$v_p = 0.39347(16) = 6.30 \text{ in./s} \qquad \textbf{Ans}$$

$$\alpha_m r_m = \alpha_p r_p$$

$$2.4261(1) = \alpha_p(4)$$

$$\alpha_p = 0.606525 \text{ rad/s}^2$$

$$a_t = \alpha r = 0.606525(16) = 9.7044 \text{ in./s}^2$$

$$a_n = \omega^2 r = (0.39347)^2(16) = 2.4771 \text{ in./s}^2$$

$$a_p = \sqrt{(9.7044)^2 + (2.4771)^2} = 10.0 \text{ in./s}^2 \qquad \textbf{Ans}$$

As $t \to \infty$

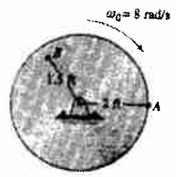
$$\omega_m = 4 \text{ rad/s}$$

$$4(1) = \omega_p(4)$$

$$\omega_p = 1 \text{ rad/s}$$

$$v_p = 1(16) = 16.0 \text{ in./s} \qquad \textbf{Ans}$$

16-~~10~~ 6. The disk is originally rotating at $\omega_0 = 8$ rad/s. If it is subjected to a constant angular acceleration of $\alpha = 6$ rad/s^2, determine the magnitudes of the velocity and the n and t components of acceleration of point A at the instant $t = 0.5$ s.



$\omega = \omega_0 + \alpha_c t$

$\omega = 8 + 6(0.5) = 11$ rad/s

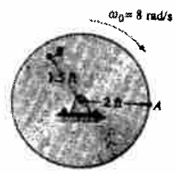
$v = r\omega; \quad v_A = \cancel{2}(11) = \cancel{22 \text{ ft/s}}$ 11 m/s **Ans**

$a_t = r\alpha; \quad (a_A)_t = \cancel{2}(6) = \cancel{12.0 \text{ ft/s}^2}$ 6 m **Ans**

$a_n = \omega^2 r; \quad (a_A)_n = (11)^2(2) = \cancel{242 \text{ ft/s}^2}$ **Ans**

121 m/s^2

16-~~11~~ 7. The disk is originally rotating at $\omega_0 = 8$ rad/s. If it is subjected to a constant angular acceleration of $\alpha = 6$ rad/s^2, determine the magnitudes of the velocity and the n and t components of acceleration of point B just after the wheel undergoes 2 revolutions.



$\omega^2 = \omega_0^2 + 2\alpha_c(\theta - \theta_0)$

$\omega^2 = (8)^2 + 2(6)[2(2\pi) - 0]$

$\omega = 14.66$ rad/s

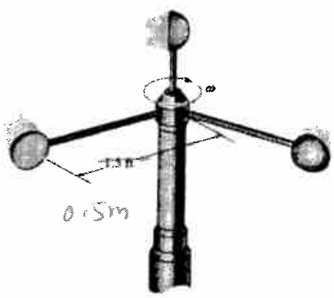
$v_B = \omega r = 14.66(\cancel{1.5}) = \cancel{22.0 \text{ ft/s}}$ 0.75 11 m/s **Ans**

$(a_B)_t = \alpha r = 6(\cancel{1.5}) = \cancel{9.00 \text{ ft/s}^2}$ 0.75 4.50 m/s^2 **Ans**

$(a_B)_n = \omega^2 r = (14.66)^2(\cancel{1.5}) = \cancel{322 \text{ ft/s}^2}$ **Ans**

0.75 161 m/s^2

***16-~~12~~ 8.** The anemometer measures the speed of the wind due to the rotation of the three cups. If during a 3-s time period a wind gust causes the cups to have an angular velocity of $\omega = (2t^2 + 3)$ rad/s, where t is in seconds, determine (a) the speed of the cups when $t = 2$ s, (b) the total distance traveled by each cup during the 3-s time period, and (c) the angular acceleration of the cups when $t = 2$ s. Neglect the size of the cups for the calculation.



$\omega = 2t^2 + 3|_{t=2\text{ s}} = 11$ rad/s

$v = \omega r = 11(\cancel{1.5}) = \cancel{16.5 \text{ ft/s}}$ 0.5 **Ans**

0.55 m/s

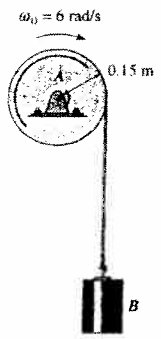
$d\theta = \omega\, dt$

$\int_0^\theta d\theta = \int_0^3 (2t^2 + 3)\, dt \qquad \theta = 27$ rad

$s = \theta r = 27(\cancel{1.5}) = \cancel{40.5 \text{ ft}}$ 0.5 13.5 m **Ans**

$\alpha = \dfrac{d\omega}{dt} = 4t\Big|_{t=2\text{ s}} = 8$ rad/s^2 ✓ **Ans**

16-13. A motor gives disk A an angular acceleration of $\alpha_A = (0.6t^2 + 0.75)\ \text{rad/s}^2$, where t is in seconds. If the initial angular velocity of the disk is $\omega_0 = 6$ rad/s, determine the magnitudes of the velocity and acceleration of block B when $t = 2$ s.



$d\omega = \alpha\, dt$

$$\int_6^{\omega} d\omega = \int_0^2 (0.6t^2 + 0.75)\, dt$$

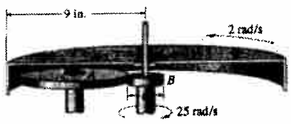
$$\omega - 6 = (0.2t^3 + 0.75t)\Big|_0^2$$

$\omega = 9.10$ rad/s

$v_B = \omega r = 9.10(0.15) = 1.37$ m/s **Ans**

$a_B = a_t = \alpha r = [0.6(2)^2 + 0.75](0.15) = 0.472\ \text{m/s}^2$ **Ans**

16-14. The turntable T is driven by the frictional idler wheel A, which simultaneously bears against the inner rim of the turntable and the motor-shaft spindle B. Determine the required diameter d of the spindle if the motor turns it at 25 rad/s and it is required that the turntable rotate at 2 rad/s.



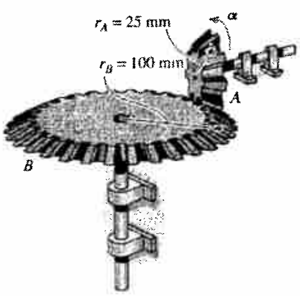
$\omega_B r_B = \omega_A r_A;\quad 25(0.5d) = \omega_A\left(\dfrac{9 - 0.5d}{2}\right)$

$$\omega_A = \frac{25d}{9 - 0.5d}$$

$\omega_A r_A = \omega_T r_T;\quad \left(\dfrac{25d}{9 - 0.5d}\right)\left(\dfrac{9 - 0.5d}{2}\right) = 2(9)$

$d = 1.44$ in. **Ans**

16-15. Gear A is in mesh with gear B as shown. If A starts from rest and has a constant angular acceleration of $\alpha_A = 2\ \text{rad/s}^2$, determine the time needed for B to attain an angular velocity of $\omega_B = 50$ rad/s.



Angular Motion: The angular acceleration of gear B must be determined first. Here, $\alpha_A r_A = \alpha_B r_B$. Then,

$$\alpha_B = \frac{r_A}{r_B}\alpha_A = \left(\frac{25}{100}\right)(2) = 0.5\ \text{rad/s}^2$$

The time for gear B to attain an angular velocity of $\omega_B = 50$ rad/s can be obtained by applying Eq. 16-5.

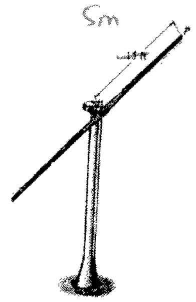
$\omega_B = (\omega_0)_B + \alpha_B t$

$50 = 0 + 0.5t$

$t = 100$ s **Ans**

10

***16-~~16~~.** The blade on the horizontal-axis windmill is turning with an angular velocity of $\omega_0 = 2$ rad/s. Determine the distance point P on the tip of the blade has traveled if the blade attains an angular velocity of $\omega = 5$ rad/s in 3 s. The angular acceleration is constant. Also, what is the magnitude of the acceleration of this point when $t = 3$ s?



$\omega = \omega_0 + \alpha_c t$

$5 = 2 + \alpha_c(3) \qquad \alpha_c = 1 \text{ rad/s}^2$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha_c t^2$

$\theta = 0 + 2(3) + \frac{1}{2}(1)(3)^2 = 10.5 \text{ rad}$

$s_P = \theta r_P = 10.5(\cancel{15}\,5) = \cancel{157.5 \text{ ft} = 158 \text{ ft}}$ 52.5 m **Ans**

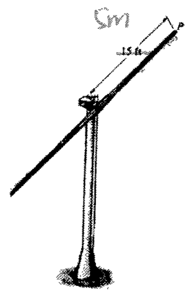
$a_t = \alpha r \qquad a_n = \omega^2 r$

$(a_P)_t = 1(\cancel{15}\,5) = \cancel{15 \text{ ft/s}^2}$ 5 m/s² $\qquad (a_P)_n = (5)^2(\cancel{15}\,5) = \cancel{375 \text{ ft/s}^2}$ 125 m/s²

$a_P = \sqrt{(a_P)_t^2 + (a_P)_n^2} = \sqrt{(\cancel{15}\,5)^2 + (\cancel{375}\,125)^2} = \cancel{375 \text{ ft/s}^2}$ 125 m/s² **Ans**

11

16-~~17~~. The blade on the horizontal-axis windmill is turning with an angular velocity of $\omega_0 = 2$ rad/s. If it is given an angular acceleration of $\alpha_c = 0.6$ rad/s², determine the angular velocity and the magnitude of acceleration of point P on the tip of the blade when $t = 3$ s.



$\omega = \omega_0 + \alpha_c t$

$\omega = 2 + 0.6(3) = 3.80 \text{ rad/s}$ **Ans**

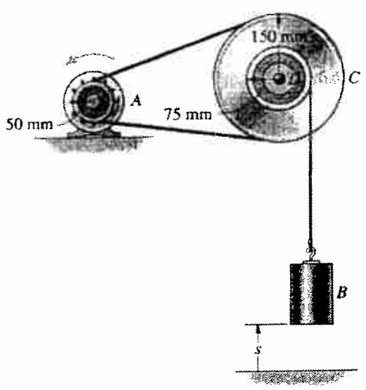
$(a_P)_t = \alpha r = 0.6(\cancel{15}\,5) = \cancel{9 \text{ ft/s}^2}$ 3.0 m/s²

$(a_P)_n = \omega^2 r = (3.80)^2(\cancel{15}\,5) = \cancel{216.60 \text{ ft/s}^2}$ 72.2 m/s²

$a_P = \sqrt{(a_P)_t^2 + (a_P)_n^2} = \sqrt{(\cancel{9}\,3)^2 + (\cancel{216.60}\,72.2)^2} = \cancel{217 \text{ ft/s}^2}$ 72.3 m/s² **Ans**

12

16-18. Starting from rest when $s = 0$, pulley A is given an angular acceleration $\alpha = (6\theta)$ rad/s^2, where θ is in radians. Determine the speed of block B when it has risen $s = 6$ m. The pulley has an inner hub D which is fixed to C and turns with it.



$\alpha_A = 6\theta_A$

$\theta_C = \dfrac{6}{0.075} = 80$ rad

$\theta_A(0.05) = 80(0.15)$

$\theta_A = 240$ rad

$\alpha\, d\theta = \omega\, d\omega$

$\int_0^{240} 6\,\theta_A\, d\theta_A = \int_0^{\omega_A} \omega_A\, d\omega_A$

$\omega_A = [6(240)^2]^{1/2} = 587.88$ rad/s

$(587.88)(0.05) = \omega_C(0.15)$

$\omega_C = 195.96$

$v_B = 195.96(0.075) = 14.7$ m/s **Ans**

Also,

$\alpha_A = 6\theta_A$

But $\alpha_A(50) = 150\alpha_C$

$\alpha_A = 3\alpha_C$

$3\alpha_C = 6\theta_A$

$\alpha_C = 2\theta_A$

But $\theta_A(50) = 150(\theta_C)$

$\theta_A = 3\theta_C$

Thus, $\alpha_C = 6\theta_C$

$\int_0^{\theta_C} 6\theta_C\, d\theta_C = \int_0^{\omega_C} \omega_C\, d\omega_C$

$6\,\theta_C^2 = \omega_C^2$

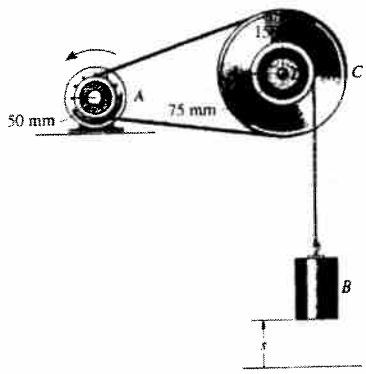
$\omega_C = \dfrac{6}{0.075} = 80$ rad

$\omega_C = \sqrt{6}(80) = 195.96$

$v_B = (195.96)(0.075) = 14.7$ m/s **Ans**

13

16-19. Starting from rest when $s = 0$, pulley A is given a constant angular acceleration $\alpha_c = 6$ rad/s^2. Determine the speed of block B when it has risen $s = 6$ m. The pulley has an inner hub D which is fixed to C and turns with it.



$\alpha_A r_A = \alpha_C r_C$

$6(50) = \alpha_C(150)$

$\alpha_C = 2$ rad/s^2

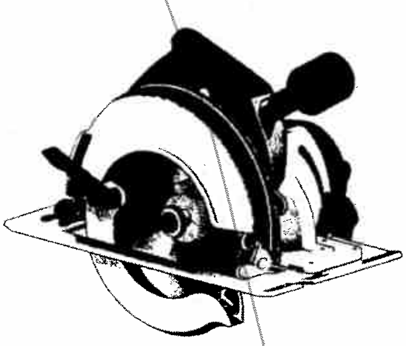
$a_B = \alpha_C r_B = 2(0.075) = 0.15$ m/s^2

$(+\uparrow)\quad v^2 = v_0^2 + 2\,a_c(s - s_0)$

$v^2 = 0 + 2(0.15)(6 - 0)$

$v = 1.34$ m/s **Ans**

***16-20.** Initially the motor on the circular saw turns its drive shaft at $\omega = (20t^{2/3})$ rad/s, where t is in seconds. If the radii of gears A and B are 0.25 in. and 1 in., respectively, determine the magnitudes of the velocity and acceleration of a tooth C on the saw blade after the drive shaft rotates $\theta = 5$ rad starting from rest.



$\omega = 20\,t^{2/3}$

$\alpha = \dfrac{d\omega}{dt} = \dfrac{40}{3}t^{-1/3}$

$d\theta = \omega\,dt$

$\int_0^\theta d\theta = \int_0^t 20\,t^{2/3}dt$

$\theta = 20(\frac{3}{5})t^{5/3}$

When $\theta = 5$ rad,

$t = 0.59139$ s

$\alpha = 15.885$ rad/s^2

$\omega = 14.091$ rad/s

$\omega_A r_A = \omega_B r_B$

$14.091(0.25) = \omega_B(1)$

$\omega_B = 3.523$ rad/s

$v_C = \omega_B r = 3.523(2.5) = 8.81$ in./s **Ans**

$\alpha_A r_A = \alpha_B r_B$

$15.885(0.25) = \alpha_B(1)$

$\alpha_B = 3.9712$ rad/s^2

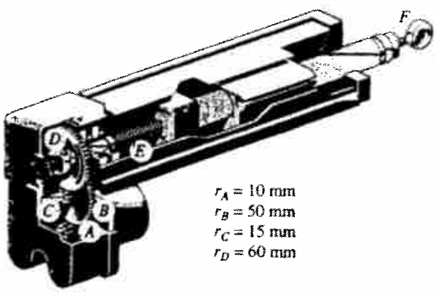
$(a_C)_t = \alpha_B r = 3.9712(2.5) = 9.928$ in./s^2

$(a_C)_n = \omega_B^2 r = (3.523)^2(2.5) = 31.025$ in./s^2

$a_C = \sqrt{(9.928)^2 + (31.025)^2}$

$= 32.6$ in./s^2 **Ans**

16-21. Due to the screw at E, the actuator provides linear motion to the arm at F when the motor turns the gear at A. If the gears have the radii listed in the figure, and the screw at E has a pitch $p = 2$ mm, determine the speed at F when the motor turns A at $\omega_A = 20$ rad/s. *Hint:* The screw pitch indicates the amount of advance of the screw for each full revolution.



$\omega_A r_A = \omega_B r_B$

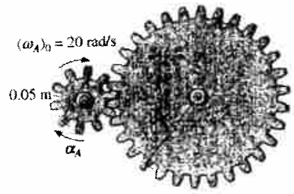
$\omega_C r_C = \omega_D r_D$

Thus,

$$\omega_D = \frac{r_A}{r_B}\frac{r_C}{r_D}\omega_A = \frac{10}{50}\frac{15}{60}20 = 1 \text{ rad/s}$$

$$v_F = \frac{1 \text{ rad/s}}{2\pi \text{ rad}}\frac{1 \text{ rev}}{}(2 \text{ mm}) = 0.318 \text{ mm/s} \quad \textbf{Ans.}$$

16-22. A motor gives gear A an angular acceleration of $\alpha_A = (0.25\theta^3 + 0.5)$ rad/s^2, where θ is in radians. If this gear is initially turning at $(\omega_A)_0 = 20$ rad/s, determine the angular velocity of gear B after A undergoes an angular displacement of 10 rev.



$$\alpha_A = 0.25\theta^3 + 0.5$$

$$\alpha\, d\theta = \omega\, d\omega$$

$$\int_0^{20\pi}(0.25\theta^3 + 0.5)d\theta_A = \int_{20}^{\omega_A} \omega_A\, d\omega_A$$

$$(0.0625\theta^4 + 0.5\theta)\Big|_0^{20\pi} = \frac{1}{2}(\omega_A)^2\Big|_{20}^{\omega_A}$$

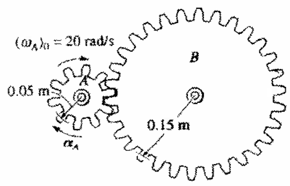
$$\omega_A = 1395.94 \text{ rad/s}$$

$$\omega_A r_A = \omega_B r_B$$

$$1395.94(0.05) = \omega_B(0.15)$$

$\omega_B = 465$ rad/s **Ans**

16-23. A motor gives gear A an angular acceleration of $\alpha_A = (4t^3)$ rad/s^2, where t is in seconds. If this gear is initially turning at $(\omega_A)_0 = 20$ rad/s, determine the angular velocity of gear B when $t = 2$ s.



$$\alpha_A = 4t^3$$

$$d\omega = \alpha\, dt$$

$$\int_{20}^{\omega_A} d\omega_A = \int_0^t \alpha_A\, dt = \int_0^t 4t^3\, dt$$

$$\omega_A = t^4 + 20$$

When $t = 2$ s,

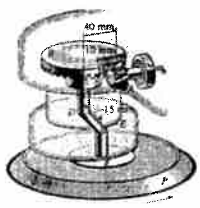
$$\omega_A = 36 \text{ rad/s}$$

$$\omega_A r_A = \omega_B r_B$$

$$36(0.05) = \omega_B(0.15)$$

$\omega_B = 12$ rad/s **Ans**

***16-24.** For a short time a motor of the random-orbit sander drives the gear A with an angular velocity of $\omega_A = 40(t^3 + 6t)$ rad/s, where t is in seconds. This gear is connected to gear B, which is fixed connected to the shaft CD. The end of this shaft is connected to the eccentric spindle EF and pad P, which causes the pad to orbit around shaft CD at a radius of 15 mm. Determine the magnitudes of the velocity and the tangential and normal components of acceleration of the spindle EF when $t = 2$ s after starting from rest.



$$\omega_A r_A = \omega_B r_B$$

$$\omega_A(10) = \omega_B(40)$$

$$\omega_B = \frac{1}{4}\omega_A$$

$$v_E = \omega_B r_E = \frac{1}{4}\omega_A(0.015) = \frac{1}{4}(40)\left(t^3 + 6t\right)(0.015)\Big|_{t=2}$$

$v_E = 3$ m/s **Ans**

$$\alpha_A = \frac{d\omega_A}{dt} = \frac{d}{dt}\left[40\left(t^3 + 6t\right)\right] = 120t^2 + 240$$

$$\alpha_A r_A = \alpha_B r_B$$

$$\alpha_A(10) = \alpha_B(40)$$

$$\alpha_B = \frac{1}{4}\alpha_A$$

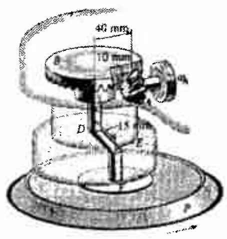
$$(a_E)_t = \alpha_B r_E = \frac{1}{4}\left(120t^2 + 240\right)(0.015)\Big|_{t=2}$$

$(a_E)_t = 2.70$ m/s^2 **Ans**

$$(a_E)_n = \omega_B^2 r_E = \left[\frac{1}{4}(40)\left(t^3 + 6t\right)\right]^2(0.015)\Big|_{t=2}$$

$(a_E)_n = 600$ m/s^2 **Ans**

16-25. For a short time the motor of the random-orbit sander drives the gear A with an angular velocity of $\omega_A = (5\theta^2)$ rad/s, where θ is in radians. This gear is connected to gear B, which is fixed connected to the shaft CD. The end of this shaft is connected to the eccentric spindle EF and pad P, which causes the pad to orbit around shaft CD at a radius of 15 mm. Determine the magnitudes of the velocity and the tangential and normal components of acceleration of the spindle EF when $\theta = 0.5$ revolutions starting from rest.



$\omega_A(10) = \omega_B(40)$

$\omega_B = \frac{1}{4}\omega_A$

$0.5 \text{ rev} = \pi \text{ rad}$

$v_E = \omega_B r_E = \frac{1}{4}\omega_A(0.015) = \frac{1}{4}(5\theta^2)(0.015)\Big|_{\theta=\pi}$

$v_E = 0.185$ m/s **Ans**

$\alpha_A d\theta = \omega_A d\omega_A$

$\alpha_A d\theta = (5\theta^2)(10\theta\, d\theta)$

$\alpha_A = 50\theta^3$

$\alpha_A r_A = \alpha_B r_B$

$\alpha_A(10) = \alpha_B(40)$

$\alpha_B = \frac{1}{4}\alpha_A$

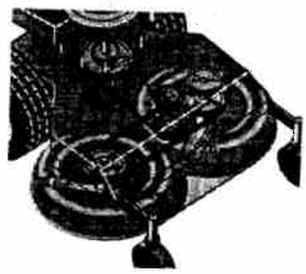
$(a_E)_t = \alpha_B r_E = \frac{1}{4}(50\theta^3)(0.015)\Big|_{\theta=\pi}$

$(a_E)_t = 5.81$ m/s^2 **Ans**

$(a_E)_n = \omega_B^2 r_E = \left[\frac{1}{4}(5\theta^2)\right]^2(0.015)\Big|_{\theta=\pi}$

$(a_E)_n = 2.28$ m/s^2 **Ans**

16-26. The engine shaft S on the lawnmower rotates at a constant angular rate of 40 rad/s. Determine the magnitudes of the velocity and acceleration of point P on the blade and the distance P travels in 3 seconds. The shaft S is connected to the driver pulley A, and the motion is transmitted to the belt that passes over the idler pulleys at B and C and to the pulley at D. This pulley is connected to the blade and to another belt that drives the other blade.



$\omega_A = 40$ rad/s $\quad \alpha_A = 0$

$\theta = \theta_0 + \omega t$

$\theta_A = 0 + 40(3) = 120$ rad

$\theta_A r_A = \theta_D r_D$

$120(75) = \theta_D(50)$

$\theta_D = 180$ rad

$s_P = r_P\theta_D = 0.2(180) = 36$ m **Ans**

$\omega_A r_A = \omega_D r_D$

$40(75) = \omega_D(50)$

$\omega_D = 60$ rad/s

$v_P = r_P\omega_D = 0.2(60) = 12$ m/s **Ans**

Also,

$v_P = \frac{s_P}{t} = \frac{36 \text{ m}}{3 \text{ s}} = 12$ m/s **Ans**

$\alpha_D = 0$

Thus,

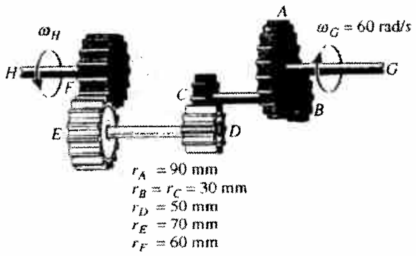
$(a_P)_t = \alpha_D r_P = 0$

$(a_P)_n = \omega_D^2 r_P = (60)^2(0.2) = 720$ m/s^2

$a_P = 720$ m/s^2 **Ans**

14

16-27. The operation of "reverse" for a three-speed automotive transmission is illustrated schematically in the figure. If the crank shaft G is turning with an angular speed of 60 rad/s, determine the angular speed of the drive shaft H. Each of the gears rotates about a fixed axis. Note that gears A and B, C and D, E and F are in mesh. The radii of each of these gears are reported in the figure.



$$60(90) = \omega_{BC}(30)$$

$$\omega_{BC} = 180 \text{ rad/s}$$

$$180(30) = 50(\omega_{DE})$$

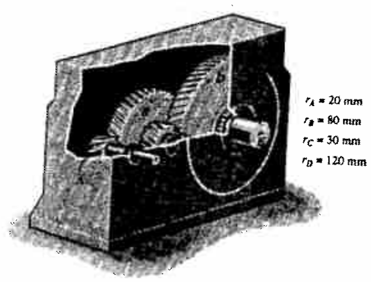
$$\omega_{DE} = 108 \text{ rad/s}$$

$$108(70) = (60)(\omega_H)$$

$$\omega_H = 126 \text{ rad/s} \qquad \textbf{Ans}$$

15

***16-28.** Morse Industrial manufactures the speed reducer shown. If a motor drives the gear shaft S with an angular acceleration of $\alpha = (0.4e^t)$ rad/s^2, where t is in seconds, determine the angular velocity of shaft E when $t = 2$ s after starting from rest. The radius of each gear is listed in the figure. Note that gears B and C are fixed connected to the same shaft.



$$\alpha = \frac{d\omega}{dt} = 0.4e^t$$

$$\int_1^{\omega} d\omega = \int_0^t 0.4e^t\, dt$$

$$\omega_S = 0.4e^t|_0^2 = 0.4\left(e^2 - 1\right) = 2.556 \text{ rad/s}$$

$$\omega_S r_A = \omega_B r_B$$

$$2.556(20) = \omega_B(80)$$

$$\omega_B = 0.6389 \text{ rad/s}$$

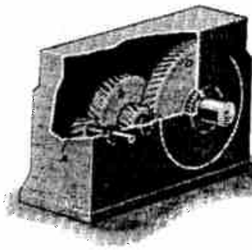
$$\omega_B r_C = \omega_D r_D$$

$$0.6389(30) = \omega_D(120)$$

$$\omega_D = 0.160 \text{ rad/s}$$

$$\omega_E = 0.160 \text{ rad/s} \qquad \textbf{Ans}$$

***16-29.** Morse Industrial manufactures the speed reducer shown. If a motor drives the gear shaft S with an angular acceleration of $\alpha = (4\omega^{-3})$ rad/s^2, where ω is in rad/s, determine the angular velocity of shaft E when $t = 2$ s after starting from an angular velocity of 1 rad/s when $t = 0$. The radius of each gear is listed in the figure. Note that gears B and C are fixed connected to the same shaft.



$$\alpha = \frac{d\omega}{dt} = 4\omega^{-3}$$

$$\int_1^{\omega} \omega^3 d\omega = \int_0^t 4\,dt$$

$$\frac{1}{4}\omega^4\Big|_1^{\omega} = 4t\Big|_0^t$$

$$\frac{1}{4}\left(\omega^4 - 1\right) = 4t$$

$$\omega_S = (16t+1)^{\frac{1}{4}}\Big|_{t=2} = 2.397 \text{ rad/s}$$

$$\omega_S r_A = \omega_B r_B$$

$$2.397(20) = \omega_B(80)$$

$$\omega_B = 0.5992 \text{ rad/s}$$

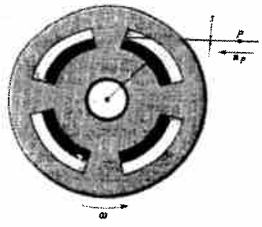
$$\omega_B r_C = \omega_D r_D$$

$$0.5992(30) = \omega_D(120)$$

$$\omega_D = 0.150 \text{ rad/s}$$

$$\omega_E = 0.150 \text{ rad/s} \qquad \textbf{Ans}$$

16-30. A tape having a thickness s wraps around the wheel which is turning at a constant rate ω. Assuming the unwrapped portion of tape remains horizontal, determine the acceleration of point P of the unwrapped tape when the radius of the wrapped tape is r. *Hint:* Since $v_P = \omega r$, take the time derivative and note that $dr/dt = \omega(s/2\pi)$.



$$v_P = \omega r$$

$$a = \frac{dv_P}{dt} = \frac{d\omega}{dt}r + \omega\frac{dr}{dt}$$

Since $\dfrac{d\omega}{dt} = 0$,

$$a = \omega\left(\frac{dr}{dt}\right)$$

In one revolution r is increased by s, so that

$$\frac{2\pi}{\theta} = \frac{s}{\Delta r}$$

Hence,

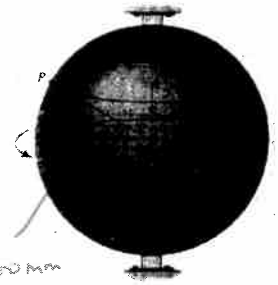
$$\Delta r = \frac{s}{2\pi}\theta$$

$$\frac{dr}{dt} = \frac{s}{2\pi}\omega$$

$$a = \frac{s}{2\pi}\omega^2 \qquad \textbf{Ans}$$

16

16-31. The sphere starts from rest at $\theta = 0°$ and rotates with an angular acceleration of $\alpha = (4\theta)$ rad/s², where θ is in radians. Determine the magnitudes of the velocity and acceleration of point P on the sphere at the instant $\theta = 6$ rad.



$\omega\, d\omega = \alpha\, d\theta$

$\int_0^{\omega} \omega\, d\omega = \int_0^{\theta} 4\theta\, d\theta$

$\omega = 2\theta$

At $\theta = 6$ rad,

$\alpha = 4(6) = 24$ rad/s², $\quad \omega = 2(6) = 12$ rad/s

$v = \omega r' = 12(\overset{200}{\cancel{8}}\cos 30°) = \cancel{83.14 \text{ in./s}}$ 2078 mm/s = 2.078 m/s

~~v = 6.93 ft/s Ans~~

$a_r = \dfrac{v^2}{r'} = \dfrac{(\overset{2078}{\cancel{83.14}})^2}{(\overset{200}{\cancel{8}}\cos 30°)} = \cancel{997.66 \text{ in./s}^2}$ 24930 mm/s² = 24.93 m/s²

$a_t = \alpha r' = 24(\overset{200}{\cancel{8}}\cos 30°) = \cancel{166.28 \text{ in./s}^2}$ 4156 mm/s² = 4.156 m/s²

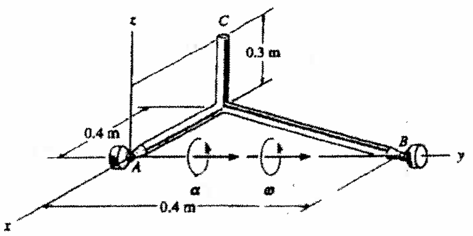
$a = \cancel{\sqrt{(997.66)^2 + (166.28)^2} = 1011.42 \text{ in./s}^2}$

$\sqrt{(24.93)^2 + (4.156)^2} = 25.27$ m/s²

~~a = 84.3 ft/s²~~ **Ans**

17

***16-32.** The rod assembly is supported by ball-and-socket joints at A and B. At the instant shown it is rotating about the y axis with an angular velocity $\omega = 5$ rad/s and has an angular acceleration $\alpha = 8$ rad/s². Determine the magnitudes of the velocity and acceleration of point C at this instant. Solve the problem using Cartesian vectors and Eqs. 16–9 and 16–13.



$\mathbf{v}_C = \boldsymbol{\omega} \times \mathbf{r}$

$\mathbf{v}_C = 5\mathbf{j} \times (-0.4\mathbf{i} + 0.3\mathbf{k}) = \{1.5\mathbf{i} + 2\mathbf{k}\}$ m/s

$v_C = \sqrt{1.5^2 + 2^2} = 2.50$ m/s **Ans**

$\mathbf{a}_C = \boldsymbol{\alpha} \times \mathbf{r} - \omega^2 \mathbf{r}$

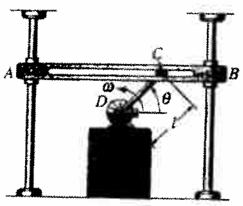
$= 8\mathbf{j} \times (-0.4\mathbf{i} + 0.3\mathbf{k}) - 5^2(-0.4\mathbf{i} + 0.3\mathbf{k})$

$= \{12.4\mathbf{i} - 4.3\mathbf{k}\}$ m/s²

$a_C = \sqrt{12.4^2 + (-4.3)^2} = 13.1$ m/s² **Ans**

18

16-33. The bar DC rotates uniformly about the shaft at D with a constant angular velocity ω. Determine the velocity and acceleration of the bar AB, which is confined by the guides to move vertically.



$y = l\sin\theta$

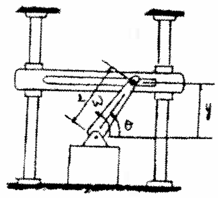
$\dot{y} = v_y = l\cos\theta\dot{\theta}$

$\ddot{y} = a_y = l\left(\cos\theta\ddot{\theta} - \sin\theta\dot{\theta}^2\right)$

Here $v_y = v_{AB}$, $a_y = a_{AB}$, and $\dot{\theta} = \omega$, $\ddot{\theta} = \alpha = 0$.

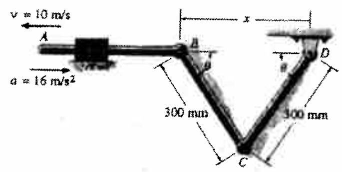
$v_{AB} = l\cos\theta(\omega) = \omega\, l\cos\theta$ **Ans**

$a_{AB} = l\left[\cos\theta(0) - \sin\theta(\omega)^2\right] = -\omega^2 l\sin\theta$ **Ans**



19

16-34. At the instant shown, $\theta = 60°$, and rod AB is subjected to a deceleration of 16 m/s² when the velocity is 10 m/s. Determine the angular velocity and angular acceleration of link CD at this instant.



$x = 2(0.3)\cos\theta$

$\dot{x} = -0.6\sin\theta\left(\dot{\theta}\right)$ (1)

$\ddot{x} = -0.6\cos\theta\left(\dot{\theta}\right)^2 - 0.6\sin\theta\left(\ddot{\theta}\right)$ (2)

Using Eqs. (1) and (2) at $\theta = 60°$, $\dot{x} = 10$ m/s, $\ddot{x} = -16$ m/s²,

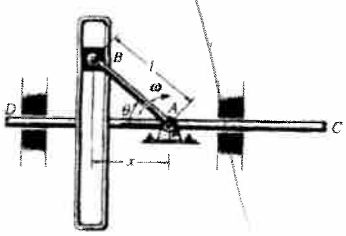
$10 = -0.6\sin 60°(\omega)$

$\omega = -19.245 = -19.2$ rad/s **Ans**

$-16 = -0.6\cos 60°(-19.245)^2 - 0.6\sin 60°(\alpha)$

$\alpha = -183$ rad/s² **Ans**

16-35. The mechanism is used to convert the constant circular motion ω of rod AB into translating motion of rod CD. Determine the velocity and acceleration of CD for any angle θ of AB.



$x = l\cos\theta$

$\dot{x} = v_x = -l\sin\theta\dot{\theta}$

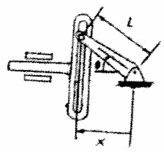
$\ddot{x} = a_x = -l\left(\sin\theta\ddot{\theta} + \cos\theta\dot{\theta}^2\right)$

Here $v_x = v_{CD}$, $a_x = a_{CD}$, and $\dot{\theta} = \omega$, $\ddot{\theta} = \alpha = 0$.

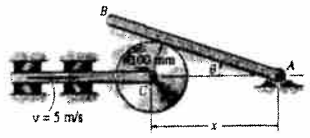
$v_{CD} = -l\sin\theta(\omega) = -\omega\, l\sin\theta$ **Ans**

$a_{CD} = -l\left[\sin\theta(0) + \cos\theta(\omega)^2\right] = -\omega^2 l\cos\theta$ **Ans**

Negative signs indicate that both v_{CD} and a_{CD} are directed opposite to positive x.



***16-36.** Determine the angular velocity of rod AB when $\theta = 30°$. The shaft and the center of the roller C move forward at a constant rate $v = 5$ m/s.



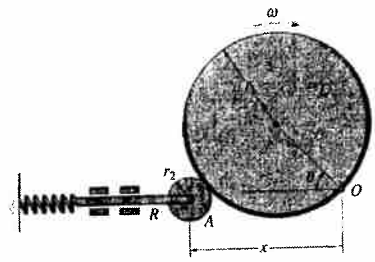
$x = 0.1\csc\theta$

$v = 0.1(-\csc\theta\cot\theta)\,\omega$

$-5 = 0.1(-\csc 30°\cot 30°)\,\omega$

$\omega = 14.4$ rad/s **Ans**

16-37. Determine the velocity of rod R for any angle θ of the cam C if the cam rotates with a constant angular velocity $\boldsymbol{\omega}$. The pin connection at O does not cause an interference with the motion of A on C.



Position Coordinate Equation : Using law of cosine.

$$(r_1 + r_2)^2 = x^2 + r_1^2 - 2r_1 x\cos\theta \qquad [1]$$

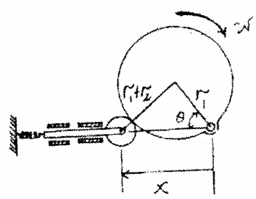
Time Derivatives : Taking the time derivative of Eq. [1], we have

$$0 = 2x\frac{dx}{dt} - 2r_1\left(-x\sin\theta\frac{d\theta}{dt} + \cos\theta\frac{dx}{dt}\right) \qquad [2]$$

However $v = \dfrac{dx}{dt}$ and $\omega = \dfrac{d\theta}{dt}$. From Eq.[2],

$$0 = xv - r_1(v\cos\theta - x\omega\sin\theta)$$

$$v = \frac{r_1 x\omega\sin\theta}{r_1\cos\theta - x} \qquad [3]$$



However, the positive root of Eq.[1] is

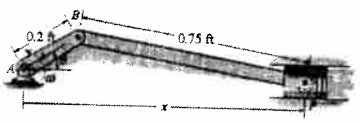
$$x = r_1\cos\theta + \sqrt{r_1^2\cos^2\theta + r_2^2 + 2r_1 r_2}$$

Substitute into Eq.[3], we have

$$v = -\left(\frac{r_1^2\omega\sin 2\theta}{2\sqrt{r_1^2\cos^2\theta + r_2^2 + 2r_1 r_2}} + r_1\omega\sin\theta\right) \qquad \textbf{Ans}$$

Note : Negative sign indicates that v is directed in the opposite direction to that of positive x.

16-38. The crankshaft AB is rotating at a constant angular velocity of $\omega = 150$ rad/s. Determine the velocity of the piston P at the instant $\theta = 30°$.



$$x = 0.2\cos\theta + \sqrt{(0.75)^2 - (0.2\sin\theta)^2}$$

$$\dot{x} = -0.2\sin\theta\dot{\theta} + \frac{1}{2}\left[(0.75)^2 - (0.2\sin\theta)^2\right]^{-\frac{1}{2}}(-2)(0.2\sin\theta)(0.2\cos\theta)\dot{\theta}$$

$$v_P = -0.2\omega\sin\theta - \left(\frac{1}{2}\right)\frac{(0.2)^2\omega\sin2\theta}{\sqrt{(0.75)^2 - (0.2\sin\theta)^2}}$$

At $\theta = 30°$, $\omega = 150$ rad/s

$$v_P = -0.2(150)\sin30° - \left(\frac{1}{2}\right)\frac{(0.2)^2(150)\sin60°}{\sqrt{(0.75)^2 - (0.2\sin30°)^2}}$$

$v_P = -18.5$ ft/s $= 18.5$ ft/s $\leftarrow$ **Ans**

16-39. At the instant $\theta = 50°$, the slotted guide is moving upward with an acceleration of $3\ \text{m/s}^2$ and a velocity of 2 m/s. Determine the angular acceleration and angular velocity of link AB at this instant. *Note:* The upward motion of the guide is in the negative y direction.

$$y = 0.3\cos\theta$$

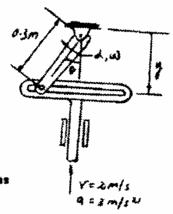
$$\dot{y} = v_y = -0.3\sin\theta\dot{\theta}$$

$$\ddot{y} = a_y = -0.3(\sin\theta\ddot{\theta} + \cos\theta\dot{\theta}^2)$$

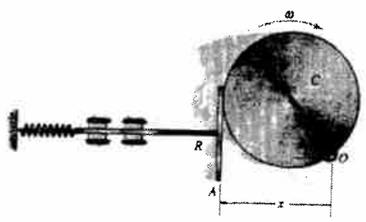
Here $v_y = -2$ m/s, $a_y = -3\ \text{m/s}^2$, and $\dot{\theta} = \omega$, $\ddot{\theta} = \alpha$, $\theta = 50°$.

$-2 = -0.3\sin50°(\omega)$ $\qquad \omega = 8.70$ rad/s **Ans**

$-3 = -0.3\left[\sin50°(\alpha) + \cos50°(8.70)^2\right]$ $\qquad \alpha = -50.5\ \text{rad/s}^2$ **Ans**



***16-40.** Determine the velocity of the rod R for any angle θ of cam C if the cam rotates with a constant angular velocity ω. The pin connection at O does not cause an interference with the motion of plate A on C.

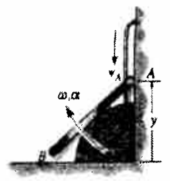


$$x = r + r\cos\theta$$

$$\dot{x} = -r\sin\theta\dot{\theta}$$

$v = -r\omega\sin\theta$ **Ans**

•16-41. The end A of the bar is moving downward along the slotted guide with a constant velocity $\mathbf{v}_A$. Determine the angular velocity $\boldsymbol{\omega}$ and angular acceleration $\boldsymbol{\alpha}$ of the bar as a function of its position y.



Position coordinate equation :

$$\sin\theta = \frac{r}{y}$$

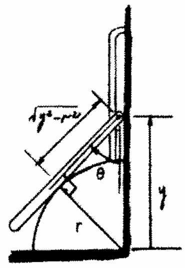
Time derivatives :

$$\cos\theta\dot{\theta} = -\frac{r}{y^2}\dot{y} \qquad \text{However, } \cos\theta = \frac{\sqrt{y^2-r^2}}{y} \text{ and } \dot{y} = -v_A,\ \dot{\theta} = \omega$$

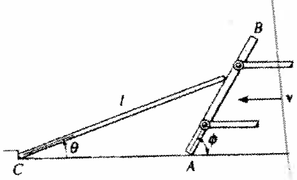
$$\left(\frac{\sqrt{y^2-r^2}}{y}\right)\omega = \frac{r}{y^2}v_A \qquad \omega = \frac{rv_A}{y\sqrt{y^2-r^2}} \qquad \textbf{Ans}$$

$$\alpha = \dot{\omega} = rv_A\left[-y^{-2}\dot{y}(y^2-r^2)^{-\frac{1}{2}} + (y^{-1})(-\tfrac{1}{2})(y^2-r^2)^{-\frac{3}{2}}(2y\dot{y})\right]$$

$$\alpha = \frac{rv_A^2(2y^2-r^2)}{y^2(y^2-r^2)^{\frac{3}{2}}} \qquad \textbf{Ans}$$



16-42. The inclined plate moves to the left with a constant velocity $\mathbf{v}$. Determine the angular velocity and angular acceleration of the slender rod of length l. The rod pivots about the step at C as it slides on the plate.



$$\frac{x}{\sin(\phi-\theta)} = \frac{l}{\sin(180^\circ-\phi)} = \frac{l}{\sin\phi}$$

$$x\sin\phi = l\sin(\phi-\theta)$$

$$\dot{x}\sin\phi = -l\cos(\phi-\theta)\dot{\theta}$$

Thus

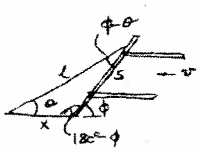
$$\omega = \frac{-v(\sin\phi)}{l\cos(\phi-\theta)} \qquad \textbf{Ans}$$

$$\ddot{x}\sin\phi = -l\cos(\phi-\theta)\ddot{\theta} - l\sin(\phi-\theta)(\dot{\theta})^2$$

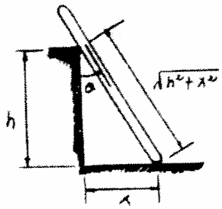
$$0 = -\cos(\phi-\theta)\alpha - \sin(\phi-\theta)\,\omega^2$$

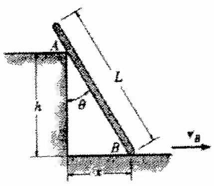
$$\alpha = \frac{-\sin(\phi-\theta)}{\cos(\phi-\theta)}\left(\frac{v^2\sin^2\phi}{l^2\cos^2(\phi-\theta)}\right)$$

$$\alpha = \frac{-v^2\sin^2\phi\sin(\phi-\theta)}{l^2\cos^3(\phi-\theta)} \qquad \textbf{Ans}$$



16-43. The bar remains in contact with the floor and with point A. If point B moves to the right with a constant velocity $\mathbf{v}_B$, determine the angular velocity and angular acceleration of the bar as a function of x.





Position coordinate equation :

$$\tan\theta = \frac{x}{h}$$

Time derivatives :

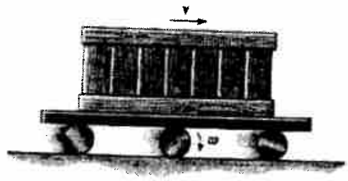
$$\sec^2\theta\dot{\theta} = \frac{1}{h}\dot{x} \qquad \text{However, } \sec\theta = \frac{\sqrt{h^2+x^2}}{h} \text{ and } \dot{x} = v_B,\ \dot{\theta} = \omega$$

$$\left(\frac{\sqrt{h^2+x^2}}{h}\right)^2\omega = \frac{1}{h}v_B \qquad \omega = \frac{h}{h^2+x^2}v_B \qquad \textbf{Ans}$$

$$\alpha = \dot{\omega} = v_B h\left[-(h^2+x^2)^{-2}(2x\dot{x})\right]$$

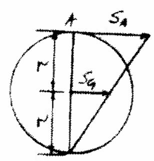
$$\alpha = \frac{-2xh}{(h^2+x^2)^2}v_B^2 \qquad \textbf{Ans}$$

***16-44.** The crate is transported on a platform which rests on rollers, each having a radius r. If the rollers do not slip, determine their angular velocity if the platform moves forward with a velocity **v**.



Position coordinate equation : From Example 16 – 3, $s_G = r\theta$. Using similar triangles

$$s_A = 2s_G = 2r\theta$$

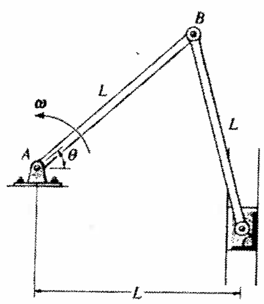


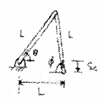
Time derivatives :

$$\dot{s}_A = v = 2r\dot{\theta} \qquad \text{Where } \dot{\theta} = \omega$$

$$\omega = \frac{v}{2r} \qquad \textbf{Ans}$$

16-45. Bar AB rotates uniformly about the fixed pin A with a constant angular velocity ω. Determine the velocity and acceleration of block C, at the instant $\theta = 60°$.





$$L\cos\theta + L\cos\phi = L$$

$$\cos\theta + \cos\phi = 1$$

$$\sin\theta\,\dot{\theta} + \sin\phi\,\dot{\phi} = 0 \qquad (1)$$

$$\cos\theta(\dot{\theta})^2 + \sin\theta\,\ddot{\theta} + \sin\phi\,\ddot{\phi} + \cos\phi\,(\dot{\phi})^2 = 0 \qquad (2)$$

When $\theta = 60°$, $\phi = 60°$,

thus, $\dot{\theta} = -\dot{\phi} = \omega$ (from Eq.(1))

$$\ddot{\theta} = 0$$

$$\ddot{\phi} = -1.155\omega^2 \qquad \text{(from Eq.(2))}$$

Also, $s_C = L\sin\phi - L\sin\theta$

$$v_C = L\cos\phi\,\dot{\phi} - L\cos\theta\,\dot{\theta}$$

$$a_C = -L\sin\phi(\dot{\phi})^2 + L\cos\phi(\ddot{\phi}) - L\cos\theta(\ddot{\theta}) + L\sin\theta(\dot{\theta})^2$$

At $\theta = 60°$, $\phi = 60°$

$$s_C = 0$$

$$v_C = L(\cos 60°)(-\omega) - L\cos 60°(\omega) = -L\omega = L\omega \uparrow \qquad \textbf{Ans}$$

$$a_C = -L\sin 60°(-\omega)^2 + L\cos 60°(-1.155\omega^2) + 0 + L\sin 60°(\omega)^2$$

$$a_C = -0.577L\omega^2 = 0.577L\omega^2 \uparrow \qquad \textbf{Ans}$$

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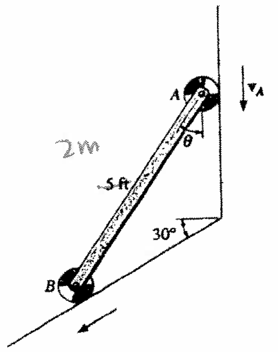
16-46. The bar is confined to move along the vertical and inclined planes. If the velocity of the roller at A is $v_A = 6$ ft/s when $\theta = 45°$, determine the bar's angular velocity and the velocity of roller B at this instant

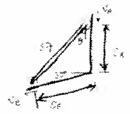
2 m/s



$s_B \cos 30° = \cancel{5}\ 2 \sin\theta$

$s_B = \cancel{5.774 \sin\theta}$ 2.31 $\sin\theta$

$\dot{s}_B = \cancel{5.774}\ 2.31 \cos\theta\ \dot{\theta}$ (1)



$2\ \cancel{5} \cos\theta = s_A + s_B \sin 30°$

$-\cancel{5}\ 2 \sin\theta\ \dot{\theta} = \dot{s}_A + \dot{s}_B \sin 30°$ (2)

Combine Eqs.(1) and (2) :

$-\cancel{5}\ 2 \sin\theta\ \dot{\theta} = -\cancel{6}\ 2 + \cancel{5.774}\ 2.31 \cos\theta(\dot{\theta})(\sin 30°)$

$\cancel{-3.536\dot{\theta} = -6 + 2.041\dot{\theta}}$ $-1.414\dot{\theta} = -2 + 0.817\dot{\theta}$

$\cancel{\omega = \dot{\theta} = 1.08 \text{ rad/s}}$ **Ans** $\omega = \dot{\theta} = 1.12$ rad/s

From Eq.(1) :

$v_B = \dot{s}_B = \cancel{5.774}\ 2.31 \cos 45°(\cancel{1.076}\ 1.12) = \cancel{4.39 \text{ ft/s}}$ **Ans** 1.83 m/s

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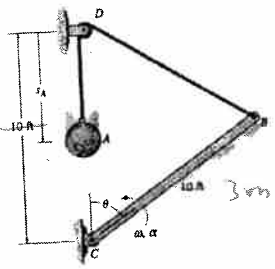
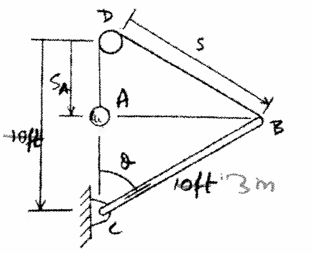
16-47. When the bar is at the angle θ, the rod is rotating clockwise at ω and has an angular acceleration of α. Determine the velocity and acceleration of the weight A at this instant. The cord is ~~20 ft~~ 6m long.



$s = \sqrt{(\cancel{10}\ 3)^2 + (\cancel{10}\ 3)^2 - 2(\cancel{10}\ 3)(\cancel{10}\ 3)\cos\theta}$

$s = \sqrt{\cancel{200}\ 18(1 - \cos\theta)}$

$s_A + \sqrt{\cancel{200}\ 18(1 - \cos\theta)} = \cancel{20}\ 6$



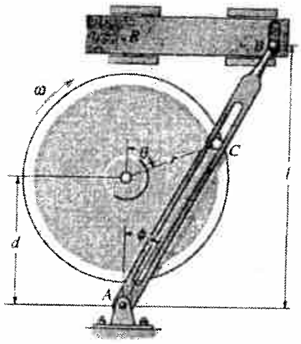
$\dot{s}_A + \cancel{7.071}\ 2.12 (1 - \cos\theta)^{-\frac{1}{2}} \sin\theta\dot{\theta} = 0$

$v_A = \dot{s}_A = \dfrac{-\cancel{7.071}\ 2.12\ \omega \sin\theta}{(1 - \cos\theta)^{\frac{1}{2}}}$ **Ans**

$\ddot{s}_A = -\cancel{7.071}\ 2.12\left(\dot{\omega}\sin\theta(1 - \cos\theta)^{-\frac{1}{2}} + \omega\cos\theta\dot{\theta}(1 - \cos\theta)^{-\frac{1}{2}} + \omega\sin\theta\left(-\frac{1}{2}\right)(1 - \cos\theta)^{-\frac{3}{2}}(\sin\theta)\dot{\theta}\right)$

$a_A = \ddot{s}_A = \cancel{7.07}\ 2.12\left[\dfrac{(\omega\sin\theta)^2}{2(1 - \cos\theta)^{\frac{3}{2}}} - \dfrac{(\alpha\sin\theta + \omega^2\cos\theta)}{(1 - \cos\theta)^{\frac{1}{2}}}\right]$ **Ans**

***16-48.** The slotted yoke is pinned at A while end B is used to move the ram R horizontally. If the disk rotates with a constant angular velocity ω, determine the velocity and acceleration of the ram. The crank pin C is fixed to the disk and turns with it.

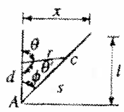


$$x = l\tan\phi \qquad [1]$$

However $\quad \dfrac{r}{\sin\phi} = \dfrac{s}{\sin(180^\circ-\theta)} = \dfrac{s}{\sin\theta} \qquad \sin\phi = \dfrac{r}{s}\sin\theta$

$$d = s\cos\phi + r\cos\theta \qquad \cos\phi = \frac{d+r\cos\theta}{s}$$

From Eq. [1] $\quad x = l\left(\dfrac{\sin\phi}{\cos\phi}\right) = l\left(\dfrac{\frac{r}{s}\sin\theta}{\frac{d+r\cos\theta}{s}}\right) = \dfrac{lr\sin\theta}{d+r\cos\theta}$



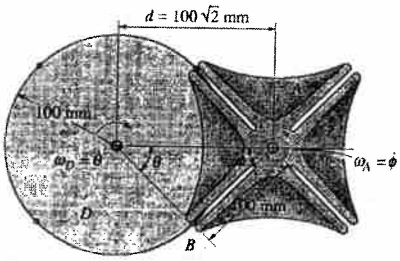
$$\dot{x} = v = \frac{(d+r\cos\theta)(lr\cos\theta\dot{\theta}) - (lr\sin\theta)(-r\sin\theta\dot{\theta})}{(d+r\cos\theta)^2} \qquad \text{Where } \dot{\theta} = \omega$$

$$= \frac{lr(r+d\cos\theta)}{(d+r\cos\theta)^2}\omega \qquad \textbf{Ans}$$

$$\ddot{x} = a = lr\omega\left[\frac{(d+r\cos\theta)^2(-d\sin\theta\dot{\theta}) - (r+d\cos\theta)(2)(d+r\cos\theta)(-r\sin\theta\dot{\theta})}{(d+r\cos\theta)^4}\right]$$

$$= \frac{lr\sin\theta(2r^2-d^2+rd\cos\theta)}{(d+r\cos\theta)^3}\omega^2 \qquad \textbf{Ans}$$

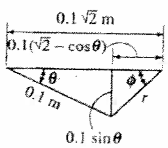
16-49. The Geneva wheel A provides intermittent rotary motion ω_A for continuous motion $\omega_D = 2$ rad/s of disk D. By choosing $d = 100\sqrt{2}$ mm, the wheel has zero angular velocity at the instant pin B enters or leaves one of the four slots. Determine the magnitude of the angular velocity ω_A of the Geneva wheel at any angle θ for which pin B is in contact with the slot.



$$\tan\phi = \frac{0.1\sin\theta}{0.1(\sqrt{2}-\cos\theta)} = \frac{\sin\theta}{\sqrt{2}-\cos\theta}$$

$$\sec^2\phi\dot{\phi} = \frac{(\sqrt{2}-\cos\theta)(\cos\theta\dot{\theta}) - \sin\theta(\sin\theta\dot{\theta})}{(\sqrt{2}-\cos\theta)^2} = \frac{\sqrt{2}\cos\theta - 1}{(\sqrt{2}-\cos\theta)^2}\dot{\theta} \qquad [1]$$

From the geometry:



$$r^2 = (0.1\sin\theta)^2 + [0.1(\sqrt{2}-\cos\theta)]^2 = 0.01(3-2\sqrt{2}\cos\theta)$$

$$\sec^2\phi = \frac{r^2}{[0.1(\sqrt{2}-\cos\theta)]^2} = \frac{0.01(3-2\sqrt{2}\cos\theta)}{[0.1(\sqrt{2}-\cos\theta)]^2} = \frac{(3-2\sqrt{2}\cos\theta)}{(\sqrt{2}-\cos\theta)^2}$$

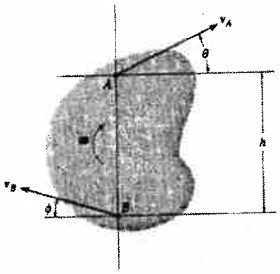
From Eq. [1]

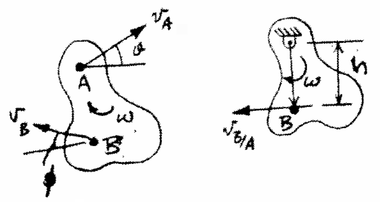
$$\frac{(3-2\sqrt{2}\cos\theta)}{(\sqrt{2}-\cos\theta)^2}\dot{\phi} = \frac{\sqrt{2}\cos\theta - 1}{(\sqrt{2}-\cos\theta)^2}\dot{\theta}$$

$$\dot{\phi} = \frac{\sqrt{2}\cos\theta - 1}{3-2\sqrt{2}\cos\theta}\dot{\theta} \qquad \text{Here } \dot{\phi} = \omega_A \text{ and } \dot{\theta} = \omega_D = 2 \text{ rad/s}$$

$$\omega_A = 2\left(\frac{\sqrt{2}\cos\theta - 1}{3-2\sqrt{2}\cos\theta}\right) \qquad \textbf{Ans}$$

16-50. If h and θ are known, and the speed of A and B is $v_A = v_B = v$, determine the angular velocity ω of the body and the direction ϕ of v_B.





$\mathbf{v}_B = \mathbf{v}_A + \omega \times \mathbf{r}_{B/A}$

$-v\cos\phi\mathbf{i} + v\sin\phi\mathbf{j} = v\cos\theta\mathbf{i} + v\sin\theta\mathbf{j} + (-\omega\mathbf{k}) \times (-h\mathbf{j})$

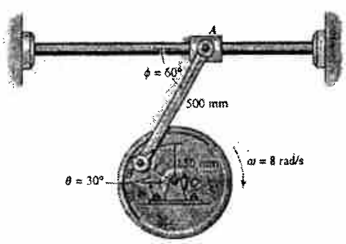
$(\overset{+}{\rightarrow})$ $\quad -v\cos\phi = v\cos\theta - \omega h \qquad (1)$

$(+\uparrow)$ $\quad v\sin\phi = v\sin\theta \qquad (2)$

From Eq. (2), $\quad \phi = \theta \qquad$ **Ans**

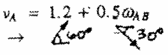
From Eq. (1), $\quad \omega = \dfrac{2v}{h}\cos\theta \qquad$ **Ans**

16-51. The wheel is rotating with an angular velocity $\omega = 8$ rad/s. Determine the velocity of the collar A at the instant $\theta = 30°$ and $\phi = 60°$. Also, sketch the location of bar AB when $\theta = 0°, 30°$, and $60°$ to show its general plane motion.



$\mathbf{v}_A = \mathbf{v}_B + \mathbf{v}_{A/B}$

$v_A = 1.2 + 0.5\omega_{AB}$

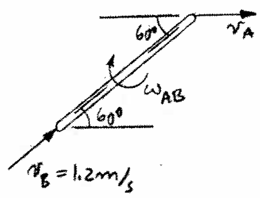


$\overset{+}{\rightarrow} \quad v_A = 1.2\cos 60° + 0.5\omega_{AB}\cos 30°$

$+\uparrow \quad 0 = 1.2\sin 60° - 0.5\omega_{AB}\sin 30°$

$\omega_{AB} = 4.16$ rad/s

$v_A = 2.40$ m/s $\rightarrow \qquad$ **Ans**



Also, $\quad \mathbf{v}_B = \omega \times \mathbf{r}_B$

$\mathbf{v}_A = \mathbf{v}_B + \omega_{AB} \times \mathbf{r}_{A/B}$

$v_A\mathbf{i} = (-8\mathbf{k}) \times (-0.15\cos 30°\mathbf{i} + 0.15\sin 30°\mathbf{j}) + (-\omega_{AB}\mathbf{k}) \times (0.5\cos 60°\mathbf{i} + 0.5\sin 60°\mathbf{j})$

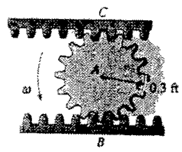
$v_A = 0.60 + 0.433\omega_{AB}$

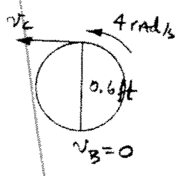
$0 = 1.039 - 0.25\omega_{AB}$

$\omega_{AB} = 4.16$ rad/s

$v_A = 2.40$ m/s $\rightarrow \qquad$ **Ans**

***16-52.** The pinion gear A rolls on the fixed gear rack B with an angular velocity $\omega = 4$ rad/s. Determine the velocity of the gear rack C.





$$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$$

$(\overset{+}{\leftarrow})$ $v_C = 0 + 4(0.6)$

$v_C = 2.40$ ft/s **Ans**

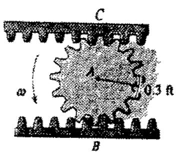
Also :

$$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$$

$$-v_C\mathbf{i} = 0 + (4\mathbf{k}) \times (0.6\mathbf{j})$$

$v_C = 2.40$ ft/s **Ans**

16-53. The pinion gear rolls on the gear racks. If B is moving to the right at 8 ft/s and C is moving to the left at 4 ft/s, determine the angular velocity of the pinion gear and the velocity of its center A.



$$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$$

$(\overset{+}{\rightarrow})$ $-4 = 8 - 0.6(\omega)$

$\omega = 20$ rad/s **Ans**

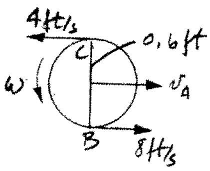
$$\mathbf{v}_A = \mathbf{v}_B + \mathbf{v}_{A/B}$$

$(\overset{+}{\rightarrow})$ $v_A = 8 - 20(0.3)$

$v_A = 2$ ft/s $\rightarrow$ **Ans**

Also :

$$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$$



$$-4\mathbf{i} = 8\mathbf{i} + (\omega\mathbf{k}) \times (0.6\mathbf{j})$$

$$-4 = 8 - 0.6\omega$$

$\omega = 20$ rad/s **Ans**

$$\mathbf{v}_A = \mathbf{v}_B + \omega \times \mathbf{r}_{A/B}$$

$$v_A\mathbf{i} = 8\mathbf{i} + 20\mathbf{k} \times (0.3\mathbf{j})$$

$v_A = 2$ ft/s $\rightarrow$ **Ans**

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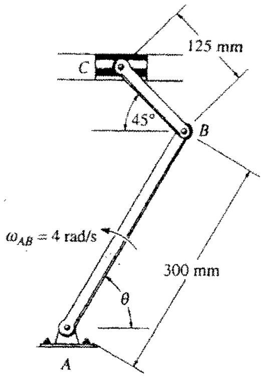
16-54. The shaper mechanism is designed to give a slow cutting stroke and a quick return to a blade attached to the slider at C. Determine the velocity of the slider block C at the instant $\theta = 60°$, if link AB is rotating at 4 rad/s.



$v_C = v_B + \omega \times r_{C/B}$

$-v_C\mathbf{i} = -4(0.3)\sin 30°\mathbf{i} + 4(0.3)\cos 30°\mathbf{j} + \omega\mathbf{k} \times (-0.125\cos 45°\mathbf{i} + 0.125\sin 45°\mathbf{j})$

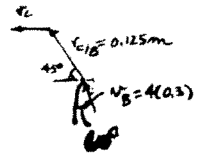
$-v_C = -1.0392 - 0.008839\omega$

$0 = 0.6 - 0.08839\omega$

Solving,

$\omega = 6.79$ rad/s

$v_C = 1.64$ m/s **Ans.**



28

16-55. Determine the velocity of the slider block at C at the instant $\theta = 45°$, if link AB is rotating at 4 rad/s.

$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$

$-v_C\mathbf{i} = -4(0.3)\cos 45°\mathbf{i} + 4(0.3)\sin 45°\mathbf{j} + \omega\,\mathbf{k} \times (-0.125\cos 45°\mathbf{i} + 0.125\sin 45°\mathbf{j})$

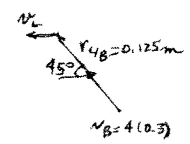
$-v_C = -0.8485 - 0.08839\omega$

$0 = 0.8485 - 0.08839\,\omega$

Solving,

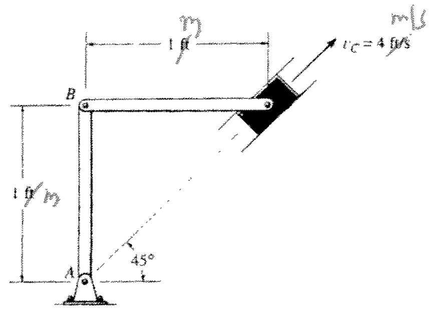
$\omega = 9.60$ rad/s

$v_C = 1.70$ m/s **Ans**



29

***16-56.** The velocity of the slider block C is ~~4 ft/s~~ m/s up the inclined groove. Determine the angular velocity of links AB and BC and the velocity of point B at the instant shown.



For link BC

$\mathbf{v}_C = \{-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j}\}$ ~~ft/s~~ m/s $\quad \mathbf{v}_B = -v_B\mathbf{i} \quad \omega = \omega_{BC}\mathbf{k}$

$\mathbf{r}_{A/B} = \{1\mathbf{i}\}$ ~~ft~~ m

$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$

$-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j} = -v_B\mathbf{i} + (\omega_{BC}\mathbf{k}) \times (1\mathbf{i})$

$-4\cos 45°\mathbf{i} + 4\sin 45°\mathbf{j} = -v_B\mathbf{i} + \omega_{BC}\mathbf{j}$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

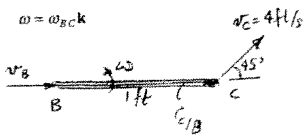
$-4\cos 45° = -v_B \qquad v_B = 2.83$ ~~ft/s~~ m/s **Ans**

$4\sin 45° = \omega_{BC} \qquad \omega_{BC} = 2.83$ rad/s **Ans**

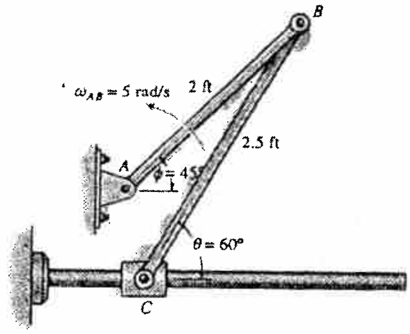
For link AB : Link AB rotates about the fixed point A. Hence

$v_B = \omega_{AB} r_{AB}$

$2.83 = \omega_{AB}(1) \qquad \omega_{AB} = 2.83$ rad/s **Ans**



16-57. Rod AB is rotating with an angular velocity $\omega_{AB} = 5$ rad/s. Determine the velocity of the collar C at the instant $\theta = 60°$ and $\phi = 45°$. Also, sketch the location of bar BC when $\theta = 30°$, $60°$ and $45°$ to show its general plane motion.



$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$

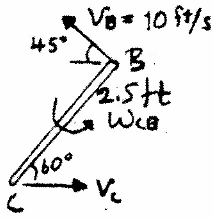
$$\begin{bmatrix} v_C \\ \rightarrow \end{bmatrix} = \begin{bmatrix} 10 \\ \searrow 45° \end{bmatrix} + \begin{bmatrix} \omega_{CB}(2.5) \\ \nwarrow 30° \end{bmatrix}$$

$(\xrightarrow{+})$ $\quad v_C = -10\cos 45° + \omega_{CB}(2.5)(\cos 30°)$

$(+\uparrow)$ $\quad 0 = 10\sin 45° - \omega_{CB}(2.5)(\sin 30°)$

$v_C = 5.18$ ft/s $\rightarrow$ **Ans**

$\omega_{CB} = 5.66$ rad/s



Also,

$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A}$

$\mathbf{v}_C = \mathbf{v}_B + \omega_{CB} \times \mathbf{r}_{C/B}$

$v_C\mathbf{i} = (5\mathbf{k}) \times (2\cos 45°\mathbf{i} + 2\sin 45°\mathbf{j}) + (\omega_{CB}\,\mathbf{k}) \times (-2.5\cos 60°\mathbf{i} - 2.5\sin 60°\mathbf{j})$

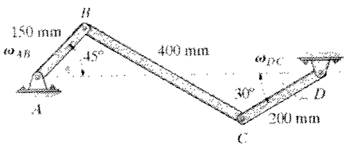
$(\xrightarrow{+})$ $\quad v_C = -7.07 + 2.17\omega_{CB}$

$(+\uparrow)$ $\quad 0 = 7.07 - 1.25\omega_{CB}$

$\omega_{CB} = 5.66$ rad/s

$v_C = 5.18$ ft/s $\rightarrow$ **Ans**

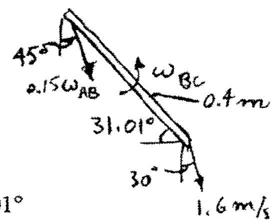
16–58. If rod CD is rotating with an angular velocity $\omega_{DC} = 8$ rad/s, determine the angular velocities of rods AB and CB at the instant shown.



$\mathbf{v}_B = \mathbf{v}_C + \mathbf{v}_{B/C}$

$0.15\omega_{AB} = 1.6 + \omega_{BC}(0.4)$

45° ↘ 30° ↘ ↙ 31.01°



$(\xrightarrow{+})\quad 0.15\omega_{AB}\sin 45° = 1.6\sin 30° - \omega_{BC}(0.4)\sin 31.01°$

$(+\downarrow)\quad 0.15\omega_{AB}\cos 45° = 1.6\cos 30° + \omega_{BC}(0.4)\cos 31.01°$

$\omega_{BC} = -1.0669 = 1.07$ rad/s **Ans**

$\omega_{AB} = 9.62$ rad/s **Ans**

Also:

$\mathbf{v}_B = \mathbf{v}_C + \omega \times \mathbf{r}_{B/C}$

$$(0.15\omega_{AB}\sin 45°\mathbf{i} - 0.15\omega_{AB}\cos 45°\mathbf{j}) = (1.6\sin 30°\mathbf{i} - 1.6\cos 30°\mathbf{j}) + (\omega_{BC}\mathbf{k}) \times (-0.4\cos 31.01°\mathbf{i} + 0.4\sin 31.01°\mathbf{j})$$

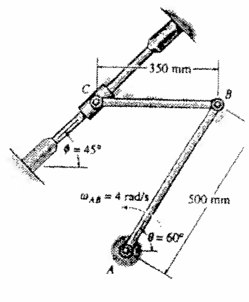
$0.15\omega_{AB}\sin 45° = 1.6\sin 30° - \omega_{BC}(0.4\sin 31.01°)$

$-0.15\omega_{AB}\cos 45° = -1.6\cos 30° - \omega_{BC}(0.4\cos 31.01°)$

$\omega_{BC} = 1.07$ rad/s **Ans**

$\omega_{AB} = 9.62$ rad/s **Ans**

16-59. The angular velocity of link AB is $\omega_{AB} = 4$ rad/s. Determine the velocity of the collar at C and the angular velocity of link CB at the instant $\theta = 60°$ and $\phi = 45°$. Link CB is horizontal at this instant. Also, sketch the location of link CB when $\theta = 30°$, $60°$, and $90°$ to show its general plane motion.

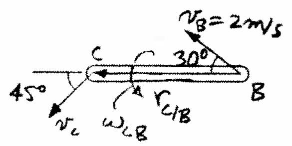


For link AB : Link AB rotates about the fixed point A . Hence

$$v_B = \omega_{AB} r_{AB}$$

$$= 4(0.5) = 2 \text{ m/s}$$

For link CB



$\mathbf{v}_B = \{-2\cos 30°\mathbf{i} + 2\sin 30°\mathbf{j}\}$ m/s $\quad \mathbf{v}_C = -v_C\cos 45°\mathbf{i} - v_C\sin 45°\mathbf{j}$

$\omega = \omega_{CB}\mathbf{k} \quad \mathbf{r}_{C/B} = \{-0.35\mathbf{i}\}$ m

$$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$$

$$-v_C\cos 45°\mathbf{i} - v_C\sin 45°\mathbf{j} = (-2\cos 30°\mathbf{i} + 2\sin 30°\mathbf{j}) + (\omega_{CB}\mathbf{k}) \times (-0.35\mathbf{i})$$

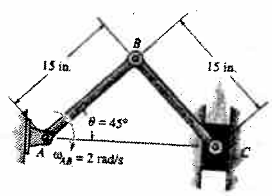
$$-v_C\cos 45°\mathbf{i} - v_C\sin 45°\mathbf{j} = -2\cos 30°\mathbf{i} + (2\sin 30° - 0.35\omega_{CB})\mathbf{j}$$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

$-v_C\cos 45° = -2\cos 30° \qquad v_C = 2.45$ m/s ↙ **Ans**

$-2.45\sin 45° = 2\sin 30° - 0.35\omega_{CB} \qquad \omega_{CB} = 7.81$ rad/s ↻ **Ans**

***16-60.** The link AB has a clockwise angular velocity of 2 rad/s. Determine the velocity of block C at the instant $\theta = 45°$. Also, sketch the location of link BC when $\theta = 60°$, $45°$, and $30°$ to show its general plane motion.

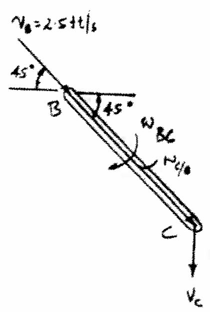


For link AB : Link AB rotates about the fixed point A. Hence

$$v_B = \omega_{AB} r_{AB}$$

$$= 2\left(\frac{15}{12}\right) = 2.5 \text{ ft/s}$$

For link BC



$\mathbf{v}_B = \{2.5\cos 45°\mathbf{i} - 2.5\sin 45°\mathbf{j}\}$ ft/s $\quad \mathbf{v}_C = -v_C\mathbf{j} \quad \omega = -\omega_{BC}\mathbf{k}$

$\mathbf{r}_{C/B} = \{1.25\cos 45°\mathbf{i} - 1.25\sin 45°\mathbf{j}\}$ ft

$$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$$

$$-v_C\mathbf{j} = (2.5\cos 45°\mathbf{i} - 2.5\sin 45°\mathbf{j}) + (-\omega_{BC}\mathbf{k}) \times (1.25\cos 45°\mathbf{i} - 1.25\sin 45°\mathbf{j})$$

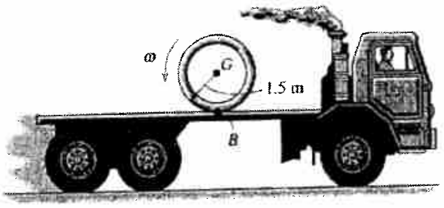
$$-v_C\mathbf{j} = (2.5\cos 45° - 1.25\sin 45°\omega_{BC})\mathbf{i} - (2.5\sin 45° + 1.25\cos 45°\omega_{BC})\mathbf{j}$$

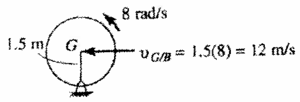
Equating the $\mathbf{i}$ and $\mathbf{j}$ components yields :

$0 = 2.5\cos 45° - 1.25\sin 45°\omega_{BC} \qquad \omega_{BC} = 2$ rad/s

$-v_C = -[2.5\sin 45° + 1.25\cos 45°(2)] \qquad v_C = 3.54$ ft/s ↓ **Ans**

16-61. At the instant shown, the truck is traveling to the right at 3 m/s, while the pipe is rolling counterclockwise at $\omega = 8$ rad/s without slipping at B. Determine the velocity of the pipe's center G.





$\mathbf{v}_G = \mathbf{v}_B + \mathbf{v}_{G/B}$

$\underset{\rightarrow}{v_G} = \underset{\rightarrow}{3} + \underset{\leftarrow}{12}$

$v_G = 9 \text{ m/s} \leftarrow$ **Ans**

Also:

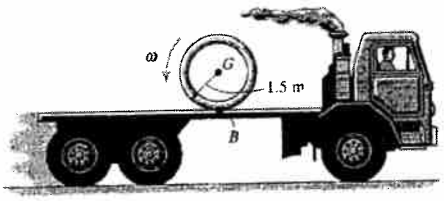
$\mathbf{v}_G = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{G/B}$

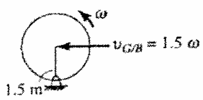
$v_G\mathbf{i} = 3\mathbf{i} + (8\mathbf{k}) \times (1.5\mathbf{j})$

$v_G = 3 - 12$

$v_G = -9 \text{ m/s} = 9 \text{ m/s} \leftarrow$ **Ans**

16-62. At the instant shown, the truck is traveling to the right at 8 m/s. If the spool does not slip at B, determine its angular velocity so that its mass center G appears to an observer on the ground to remain stationary.





$\mathbf{v}_G = \mathbf{v}_B + \mathbf{v}_{G/B}$

$0 = \underset{\rightarrow}{8} + \underset{\leftarrow}{1.5\omega}$

$\omega = \frac{8}{1.5} = 5.33$ rad/s **Ans**

Also:

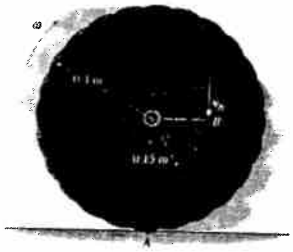
$\mathbf{v}_G = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{G/B}$

$0\mathbf{i} = 8\mathbf{i} + (\omega\mathbf{k}) \times (1.5\mathbf{j})$

$0 = 8 - 1.5\omega$

$\omega = \frac{8}{1.5} = 5.33$ rad/s **Ans**

16-63. If, at a given instant, point B has a downward velocity of $v_B = 3$ m/s, determine the velocity of point A at this instant. Notice that for this motion to occur, the wheel must slip at A.



$\mathbf{v}_A = \mathbf{v}_B + \omega \times \mathbf{r}_{A/B}$

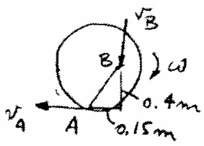
$-v_A \mathbf{i} = -3\mathbf{j} + (-\omega\mathbf{k}) \times (-0.15\mathbf{i} - 0.4\mathbf{j})$

$(\overset{+}{\rightarrow})$ $\quad -v_A = -\omega(0.4)$

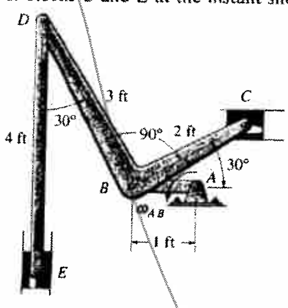
$(+\uparrow)$ $\quad 0 = -3 + \omega(0.15)$

$\omega = 20$ rad/s

$v_A = 8$ m/s $\leftarrow$ **Ans**



***16-64.** If the link AB is rotating about the pin at A with an angular velocity $\omega_{AB} = 5$ rad/s, determine the velocities of blocks C and E at the instant shown.



$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$

$v_C = 5 + \omega(2)$
$\leftarrow \quad \downarrow \quad \searrow 30°$

$\overset{+}{\leftarrow}$ $\quad v_C = 0 + \omega(2)\sin 30°$

$+\downarrow$ $\quad 0 = 5 - \omega(2)\cos 30°$

$\omega = 2.887$ rad/s

$v_C = 2.89$ ft/s **Ans**

$\mathbf{v}_D = \mathbf{v}_B + \mathbf{v}_{D/B}$

$v_D = 5 + 2.887(3) + \omega_{DE}(4)$
$\downarrow \quad \swarrow 60° \quad \rightarrow$

$\mathbf{v}_E = \mathbf{v}_D + \mathbf{v}_{E/D}$

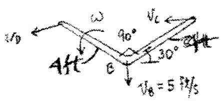
$v_E = 5 + 2.887(3) + \omega_{DE}(4)$
$\downarrow \quad \downarrow \quad \swarrow 60° \quad \rightarrow$

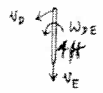
$\overset{+}{\rightarrow}$ $\quad 0 = 0 - 7.500 + \omega_{DE}(4)$

$\omega_{DE} = 1.875$ rad/s

$+\downarrow$ $\quad v_E = 5 + 4.330$

$v_E = 9.33$ ft/s $\downarrow$ **Ans**





Also :

$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$

$-v_C\mathbf{i} = -5\mathbf{j} + (\omega\mathbf{k}) \times (2\cos 30°\mathbf{i} + 2\sin 30°\mathbf{j})$

$-v_C = 0 - \omega$

$0 = -5 + 1.732\omega$

$\omega = 2.887$ rad/s

$v_C = 2.89$ ft/s **Ans**

$\mathbf{v}_D = \mathbf{v}_B + \omega \times \mathbf{r}_{D/B}$

$\mathbf{v}_D = -5\mathbf{j} + (2.887\mathbf{k}) \times (-3\sin 30°\mathbf{i} + 3\cos 30°\mathbf{j})$

$\mathbf{v}_D = \{-7.5\mathbf{i} - 9.33\mathbf{j}\}$

$\mathbf{v}_E = \mathbf{v}_D + \omega_{DE} \times \mathbf{r}_{E/D}$

$-v_E\mathbf{j} = (-7.5\mathbf{i} - 9.33\mathbf{j}) + (\omega_{DE}\mathbf{k}) \times (-4\mathbf{j})$

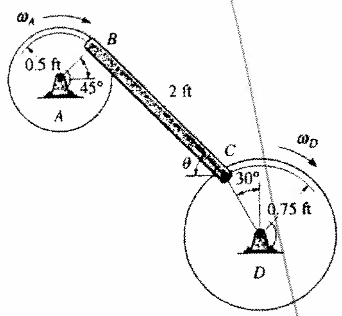
$0 = -7.5 + 4\omega_{DE}$

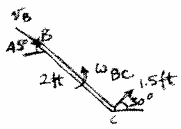
$-v_E = -9.33$

$\omega_{DE} = 1.875$ rad/s

$v_E = 9.33$ ft/s **Ans**

16-65. If disk D has a constant angular velocity $\omega_D = 2$ rad/s, determine the angular velocity of disk A at the instant $\theta = 60°$.





$\mathbf{v}_B = \mathbf{v}_C + \mathbf{v}_{B/C}$

$v_B = 1.5 + 2\omega_{BC}$

$\overset{\nwarrow}{\searrow}{}_{45°} \quad \angle 30° \quad \measuredangle 60°$

$(\overset{+}{\rightarrow}) \quad v_B \cos 45° = 1.5\cos 30° - 2\omega_{BC}\sin 60°$

$(+\downarrow) \quad v_B \sin 45° = -1.5\sin 30° + 2\omega_{BC}\cos 60°$

$\omega_{BC} = 0.75$ rad/s

$v_B = 0$

$\omega_A = \dfrac{0}{0.5} = 0$ **Ans**

Also:

$\mathbf{v}_B = \mathbf{v}_C + \omega_{BC} \times \mathbf{r}_{C/B}$

$v_B \cos 45°\mathbf{i} - v_B \sin 45°\mathbf{j} = 1.5\cos 30°\mathbf{i} + 1.5\sin 30°\mathbf{j} + (\omega_{BC}\mathbf{k}) \times (2\cos 60°\mathbf{i} - 2\sin 60°\mathbf{j})$

$v_B \cos 45° = 1.5\cos 30° + \omega_{BC}(2\sin 60°)$

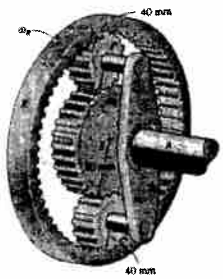
$-v_B \sin 45° = 1.5\sin 30° + \omega_{BC}(2\cos 60°)$

$\omega_{BC} = 0.75$ rad/s

$v_B = 0$

$\omega_A = \dfrac{0}{0.5} = 0$ **Ans**

16-66. The planetary gear system is used in an automatic transmission for an automobile. By locking or releasing certain gears, it has the advantage of operating the car at different speeds. Consider the case where the ring gear R is rotating at $\omega_R = 3$ rad/s, and the sun gear S is held fixed, $\omega_S = 0$. Determine the angular velocity of each of the planet gears P and shaft A.



$v_A = 3(160) = 480$ mm/s

$\mathbf{v}_B = \mathbf{v}_A + \omega \times \mathbf{r}_{B/A}$

$0 = -480\mathbf{i} + (\omega_P\mathbf{k}) \times (-80\mathbf{j})$

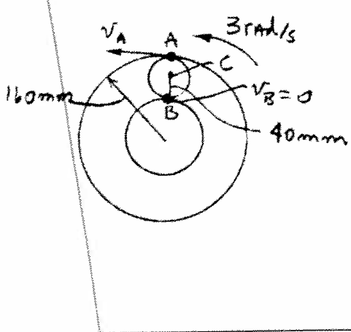
$0 = -480\mathbf{i} + 80\omega_P$

$\omega_p = 6$ rad/s ↻ **Ans**

$v_C = v_B + \omega \times \mathbf{r}_{C/B}$

$v_C = 0 + (6\mathbf{k}) \times (40\mathbf{j}) = 240\mathbf{i}$

$\omega_A = \dfrac{240}{120} = 2$ rad/s ↺ **Ans**



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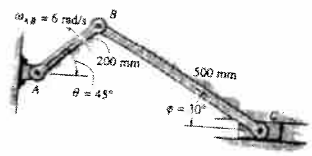
16-67. If bar AB has an angular velocity $\omega_{AB} = 6$ rad/s, determine the velocity of the slider block C at the instant $\theta = 45°$ and $\phi = 30°$. Also, sketch the location of bar BC when $\theta = 30°, 45°$, and $60°$ to show its general plane motion.



$$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$$

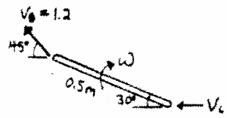
$$\begin{bmatrix} v_C \\ \leftarrow \end{bmatrix} = \begin{bmatrix} 1.2 \\ \nwarrow 45° \end{bmatrix} + \begin{bmatrix} 0.5\omega \\ 30° \end{bmatrix}$$

$(\xrightarrow{+})$ $\quad -v_C = -1.2\cos 45° - 0.5\omega\sin 30°$

$(+\uparrow)$ $\quad 0 = 1.2\sin 45° - 0.5\omega\cos 30°$

$\omega = 1.96$ rad/s

$v_C = 1.34$ m/s $\leftarrow$ **Ans**



Also,

$$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A}$$

$$\mathbf{v}_C = \mathbf{v}_B + \omega \times \mathbf{r}_{C/B}$$

$$v_C\mathbf{i} = (6\mathbf{k}) \times (0.2\cos 45°\mathbf{i} + 0.2\sin 45°\mathbf{j}) + (\omega\mathbf{k}) \times (0.5\cos 30°\mathbf{i} - 0.5\sin 30\mathbf{j})$$

$(\xrightarrow{+})$ $\quad v_C = -0.8485 + \omega(0.25)$

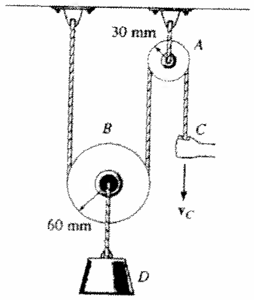
$(+\uparrow)$ $\quad 0 = 0.8485 + 0.433\omega$

$\omega = -1.96$ rad/s

$v_C = 1.34$ m/s $\leftarrow$ **Ans**

35

***16-68.** If the end of the cord is pulled downward with a speed $v_C = 120$ mm/s, determine the angular velocities of pulleys A and B and the speed of block D. Assume that the cord does not slip on the pulleys.

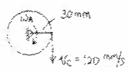


For pulley A : Motion about a fixed axis through the center applies.

$v_C = r_A\,\omega_A$

$120 = 30\omega_A$

$\omega_A = 4$ rad/s **Ans**



For pulley B : Point P' is at rest during the instant considered.

Thus,

$\mathbf{v}_P = \mathbf{v}_{P'} + \mathbf{v}_{P/P'}$

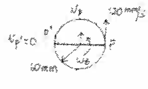
$(+\uparrow)$ $\quad 120 = 0 + 120(\omega_B)$

$\omega_B = 1$ rad/s **Ans**

$\mathbf{v}_D = \mathbf{v}_{P'} + \mathbf{v}_{D/P'}$

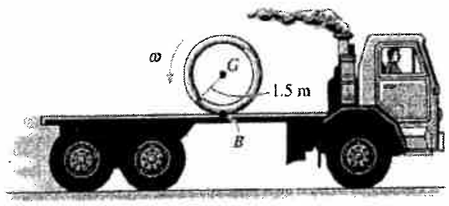
$(+\uparrow)$ $\quad v_D = 0 + 60(1)$

$v_D = 60$ mm/s **Ans**



36

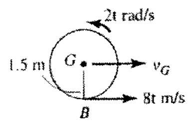
16-69. At the instant shown, the truck is traveling to the right at $8t$ m/s, while the pipe is rolling counterclockwise at $\omega = 2t$ rad/s without slipping at B. Determine the velocity of the pipe's center G.



$\mathbf{v}_G = \mathbf{v}_B + \mathbf{v}_{G/B}$

$\left[\underset{\rightarrow}{v_G}\right] = \left[\underset{\rightarrow}{8t}\right] + \left[\underset{\longleftarrow}{1.5(2t)}\right]$

$v_G = 5t$ m/s $\rightarrow$ **Ans**



Also:

$\mathbf{v}_G = \mathbf{v}_B + \omega \times \mathbf{r}_{G/B}$

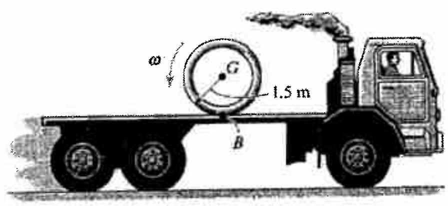
$v_G\mathbf{i} = (8t)\mathbf{i} + (2t)\mathbf{k} \times (1.5)\mathbf{j}$

$v_G = 8t - 3t$

$v_G = 5t$ m/s $\rightarrow$ **Ans**

37

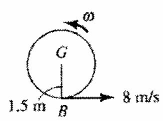
16-70. At the instant shown, the truck is traveling to the right at 12 m/s. If the pipe does not slip at B, determine its angular velocity if its mass center G appears to an observer on the ground to be moving to the right at 3 m/s.



$\mathbf{v}_G = \mathbf{v}_B + \mathbf{v}_{G/B}$

$\left[\underset{\rightarrow}{3}\right] = \left[\underset{\rightarrow}{12}\right] + \left[\underset{\leftarrow}{1.5\omega}\right]$

$\omega = \dfrac{9}{1.5} = 6$ rad/s ↺ **Ans**



Also:

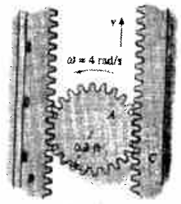
$\mathbf{v}_G = \mathbf{v}_B + \omega \times \mathbf{r}_{G/B}$

$3\mathbf{i} = 12\mathbf{i} + (\omega\mathbf{k}) \times (1.5\mathbf{j})$

$3 = 12 - 1.5\omega$

$\omega = \dfrac{9}{1.5} = 6$ rad/s ↺ **Ans**

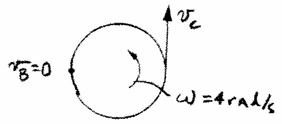
16-~~71~~38. The pinion gear A rolls on the fixed gear rack B with an angular velocity $\omega = 4$ rad/s. Determine the velocity of the gear rack C.



$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$

$$\left[\begin{matrix} v_C \\ \uparrow \end{matrix}\right] = 0 + \left[\begin{matrix} 4(0.\cancel{6}\,2) \\ \uparrow \end{matrix}\right]$$

$v_C = \cancel{2.40 \text{ ft/s}}\ 0.8 \text{ m/s} \uparrow$ **Ans**



Also,

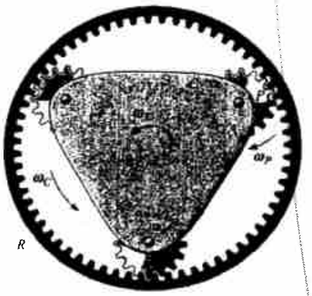
$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$v_C\mathbf{j} = 0 + (4\mathbf{k}) \times (0.\cancel{6}\,2\,\mathbf{i})$

$v_C = \cancel{2.40 \text{ ft/s}} \uparrow$ **Ans**

0.8 m/s

***16–72.** Part of an automatic transmission consists of a *fixed* ring gear R, three equal planet gears P, the sun gear S, and the planet carrier C, which is shaded. If the sun gear is rotating at $\omega_S = 6$ rad/s, determine the angular velocity ω_C of the *planet carrier*. Note that C is pin-connected to the center of each of the planet gears.



$\mathbf{v}_D = \mathbf{v}_A + \mathbf{v}_{D/A}$

$24 = 0 + 4(\omega_P)$

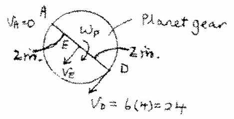
$\omega_P = 6$ rad/s

$\mathbf{v}_E = \mathbf{v}_A + \mathbf{v}_{E/A}$

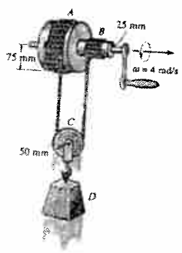
$v_E = 0 + 6(2)$

$v_E = 12$ in./s

$\omega_C = \dfrac{12}{6} = 2$ rad/s **Ans**



16-73. When the crank on the Chinese windlass is turning, the rope on shaft A unwinds while that on shaft B winds up. Determine the speed at which the block D lowers if the crank is turning with an angular velocity $\omega = 4$ rad/s. What is the angular velocity of the pulley at C? The rope segments on each side of the pulley are both parallel and vertical, and the rope does not slip on the pulley.



$v_P = \omega r_A = 4(75) = 300$ mm/s $\downarrow$

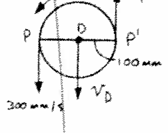
$v_{P'} = \omega r_B = 4(25) = 100$ mm/s $\uparrow$

$\mathbf{v}_{P'} = \mathbf{v}_P + \mathbf{v}_{P'/P}$

$100\mathbf{j} = -300\mathbf{j} + \omega(100)\mathbf{j}$

$(+\uparrow)\quad 100 = -300 + \omega(100)$

$\omega = 4$ rad/s **Ans**



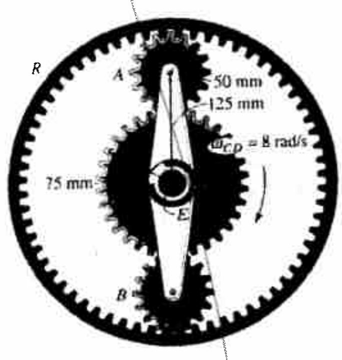
$\mathbf{v}_D = \mathbf{v}_P + \mathbf{v}_{D/P}$

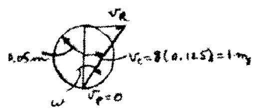
$-v_D\mathbf{j} = -300\mathbf{j} + 4(50)\mathbf{j}$

$(+\uparrow)\quad -v_D = -300 + 200$

$v_D = 100$ mm/s $\downarrow$ **Ans**

16-74. In an automobile transmission the planet pinions A and B rotate on shafts that are mounted on the planet-pinion carrier CD. As shown, CD is attached to a shaft at E which is aligned with the center of the *fixed* sun-gear S. This shaft is not attached to the sun gear. If CD is rotating at $\omega_{CD} = 8$ rad/s, determine the angular velocity of the ring gear R.





$$\mathbf{v}_C = \mathbf{v}_P + \omega \times \mathbf{r}_{C/P}$$

$$1\mathbf{i} = \mathbf{0} + (-\omega\mathbf{k}) \times (0.05\mathbf{j})$$

$$\omega = 20 \text{ rad/s}$$

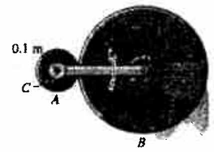
$$\mathbf{v}_R = \mathbf{v}_P + \omega \times \mathbf{r}_{R/P}$$

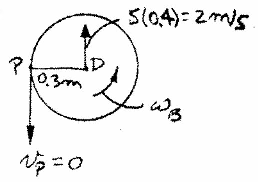
$$v_R = \mathbf{0} + (-20\mathbf{k}) \times (0.1\mathbf{j})$$

$$v_R = 2\,\mathbf{i}$$

$$\omega_R = \frac{v_R}{r} = \frac{2}{(0.125 + 0.05)} = 11.4 \text{ rad/s} \qquad \textbf{Ans}$$

16-75. The cylinder B rolls on the *fixed cylinder* A without slipping. If the connected bar CD is rotating with an angular velocity of $\omega_{CD} = 5$ rad/s, determine the angular velocity of cylinder B.





The contact point P between the cylinders has zero velocity

$$\mathbf{v}_P = \mathbf{v}_D + \mathbf{v}_{P/D}$$

$$\mathbf{0} = \begin{bmatrix} 2 \\ \uparrow \end{bmatrix} + \begin{bmatrix} \omega_B(0.3) \\ \downarrow \end{bmatrix}$$

$\omega_B = 6.67$ rad/s ↻ **Ans**

Also,

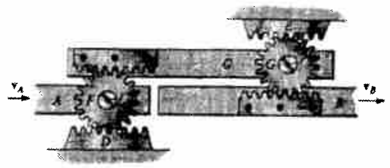
$$\mathbf{v}_P = \mathbf{v}_D + \omega_B \times \mathbf{r}_{P/D}$$

$$0 = 2\mathbf{j} + (\omega_B\,\mathbf{k}) \times (-0.3\mathbf{i})$$

$$(+\uparrow) \qquad 0 = 2 - 0.3\omega_B$$

$\omega_B = 6.67$ rad/s ↻ **Ans**

*__16-76.__ The slider mechanism is used to increase the stroke of travel of one slider with respect to that of another. As shown, when the slider A is moving forward, the attached pinion F rolls on the *fixed* rack D, forcing slider C to move forward. This in turn causes the attached pinion G to roll on the *fixed* rack E, thereby moving slider B. If A has a velocity of $v_A = 4$ ft/s at the instant shown, determine the velocity of B. $r = 0.2$ ft.



$\mathbf{v}_A = \mathbf{v}_D + \mathbf{v}_{A/D}$

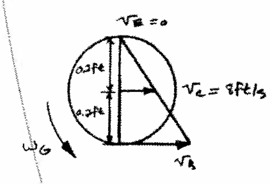
$4\mathbf{i} = \mathbf{0} + \omega_F(0.2)\mathbf{i}$

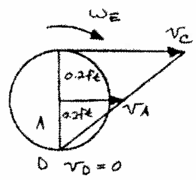
$\omega_F = 20$ rad/s

$\mathbf{v}_C = \mathbf{v}_D + \mathbf{v}_{C/D}$

$v_C\mathbf{i} = \mathbf{0} + 20(0.4)\mathbf{i}$

$v_C = 8$ ft/s





$\mathbf{v}_C = \mathbf{v}_E + \mathbf{v}_{C/E}$

$8\mathbf{i} = \mathbf{0} + \omega_G(0.2)\mathbf{i}$

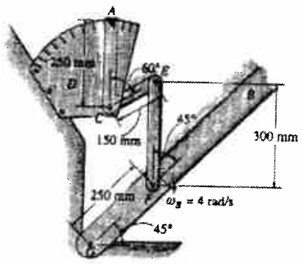
$\omega_G = 40$ rad/s

$\mathbf{v}_B = \mathbf{v}_E + \mathbf{v}_{B/E}$

$v_B\mathbf{i} = \mathbf{0} + 40(0.4)\mathbf{i}$

$v_B = 16$ ft/s $\rightarrow$ **Ans**

16-77. The gauge is used to indicate the safe load acting at the end of the boom, B, when it is in any angular position. It consists of a fixed dial plate D and an indicator arm ACE which is pinned to the plate at C and to a short link EF. If the boom is pin-connected to the trunk frame at G and is rotating downward at $\omega_B = 4$ rad/s, determine the velocity of the dial pointer A at the instant shown, i.e., when EF and AC are in the vertical position.



$v_F = \omega_B r_{GF} = (4)(0.25) = 1$ m/s

$\mathbf{v}_E = \mathbf{v}_F + \boldsymbol{\omega}_{EF} \times \mathbf{r}_{E/F}$

$v_E\cos60°\mathbf{i} - v_E\sin60°\mathbf{j} = 1\cos45°\mathbf{i} - 1\sin45°\mathbf{j} + (\omega_{EF}\mathbf{k}) \times (0.3\mathbf{i})$

$(\overset{+}{\rightarrow})$ $\quad v_E\cos60° = 1\cos45° - \omega_{EF}(0.3)$

$(+\uparrow)$ $\quad -v_E\sin60° = -1\sin45° + 0$

Solving,

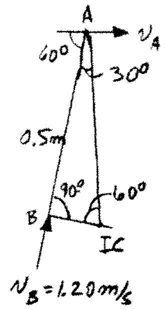
$v_E = 0.8165$ m/s, $\quad \omega_{EF} = 0.996$ rad/s

$$\omega_{ACE} = \frac{v_E}{r_{EC}} = \frac{0.8164}{0.150} = 5.44 \text{ rad/s}$$

$v_A = \omega_{ACE} r_{AC} = (5.44)(0.250) = 1.36$ m/s $\rightarrow$ **Ans**

39 26

16-78. Solve Prob. 16-51 using the method of instantaneous center of zero velocity.



$v_B = 8(0.150) = 1.20$ m/s

$r_{B/IC} = 0.5 \tan 30° = 0.28868$ m

$\omega_{AB} = \dfrac{1.20}{0.28868} = 4.157$ rad/s

$r_{A/IC} = \dfrac{0.5}{\sin 60°} = 0.5774$ m

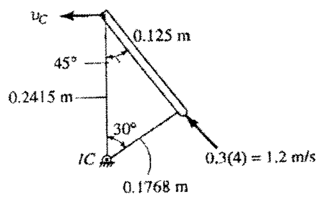
$v_A = 0.5774(4.157) = 2.40$ m/s $\rightarrow$ **Ans**

40

16-79. Solve Prob. 16-54 using the method of instantaneous center of zero velocity.

$\omega = \dfrac{1.2}{0.1768} = 6.79$ rad/s

$v_C = 6.79(0.2415) = 1.64$ m/s $\leftarrow$ **Ans**



***16-80.** Solve Prob. 16-59 using the method of instantaneous center of zero velocity.

$v_B = 4(0.5) = 2$ m/s

$\dfrac{\sin 75°}{0.350} = \dfrac{\sin 45°}{r_{B/IC}}$

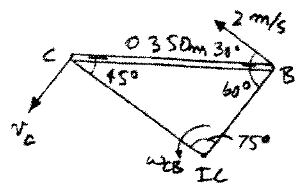
$r_{B/IC} = 0.2562$ m

$\dfrac{\sin 75°}{0.350} = \dfrac{\sin 60°}{r_{C/IC}}$

$r_{C/IC} = 0.31380$ m

$\omega_{CB} = \dfrac{2}{0.2562} = 7.806$ rad/s $= 7.81$ rad/s ↻ **Ans**

$v_C = 7.806(0.31380) = 2.45$ m/s ↙ **Ans**



41 31

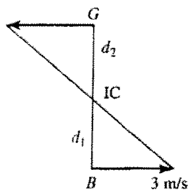
16-~~81~~. Solve Prob. 16-~~61~~ using the method of instantaneous center of zero velocity.

$v_B = 3$ m/s

$d_1 = \frac{3}{8} = 0.375$ m

$d_2 = 1.5 - 0.375 = 1.125$ m

$v_G = 8(1.125)$ m $= 9$ m/s $\leftarrow$ **Ans**



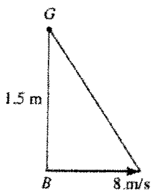
42 32

16-~~82~~. Solve Prob. 16-~~62~~ using the method of instantaneous center of zero velocity.

Mass center G is the instantaneous center.

$r\omega = v_B$

$\omega = \frac{v_B}{r} = \frac{8}{1.5} = 5.33$ rad/s **Ans**

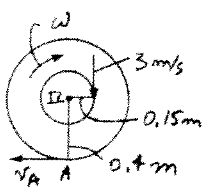


43 33

16-~~83~~. Solve Prob. 16-~~63~~ using the method of instantaneous center of zero velocity.

$\omega = \frac{3\text{ m/s}}{0.15\text{ m}} = 20$ rad/s

$v_A = (0.4)(20) = 8$ m/s $\leftarrow$ **Ans**



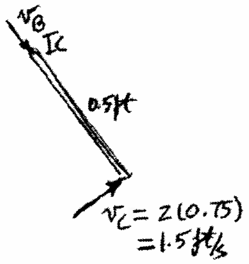
***16-84.** Solve Prob. 16-65 using the method of instantaneous center of zero velocity.

When radial lines extend from B and C, they intersect at B, thus the IC is at B and so

$v_B = 0$ **Ans**

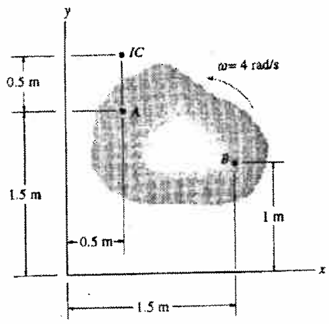
Hence

$$\omega_A = \frac{0}{0.5 \text{ ft}} = 0$$ **Ans**



44

16-85. The instantaneous center of zero velocity for the body is located at point IC (0.5 m, 2 m). If the body has an angular velocity of 4 rad/s, as shown, determine the velocity of B with respect to A.



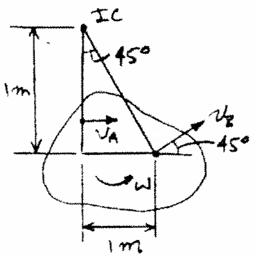
$v_A = \omega r_{A/IC} = 4(0.5) = 2 \text{ m/s} \rightarrow$

$v_B = \omega r_{B/IC} = 4\left(\sqrt{(1)^2 + (1)^2}\right) = 5.66 \text{ m/s}$

$5.66 \cos 45°\mathbf{i} + 5.66 \sin 45°\mathbf{j} = 2\mathbf{i} + v_{B/A} \cos\theta\mathbf{i} + v_{B/A} \sin\theta\mathbf{j}$

$(\overset{+}{\rightarrow})$ $(5.66)\cos 45° = 2 + v_{B/A}\cos\theta$

$(+\uparrow)$ $(5.66)\sin 45° = 0 + v_{B/A}\sin\theta$

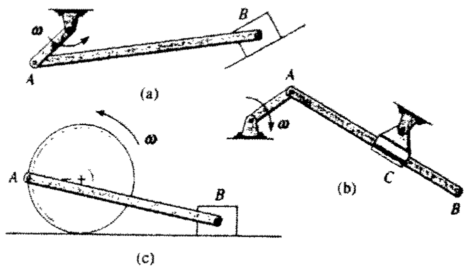


Solving,

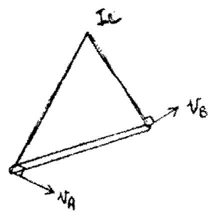
$\theta = 63.4° \angle$ **Ans**

$v_{B/A} = 4.47$ m/s **Ans**

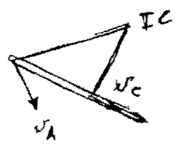
16-86. In each case show graphically how to locate the instantaneous center of zero velocity of link AB. Assume the geometry is known.



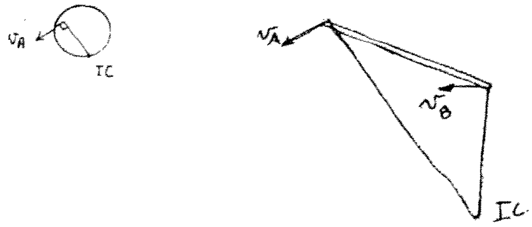
a)



b)

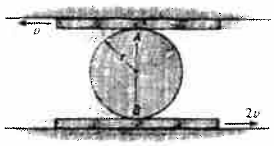


c)



46

16-~~87~~. The disk of radius r is confined to roll without slipping at A and B. If the plates have the velocities shown, determine the angular velocity of the disk.

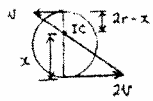


$$\frac{v}{2r-x} = \frac{2v}{x}$$

$$x = 4r - 2x$$

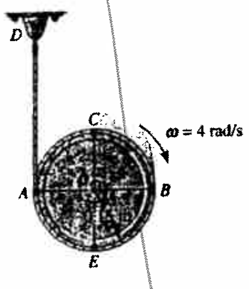
$$3x = 4r$$

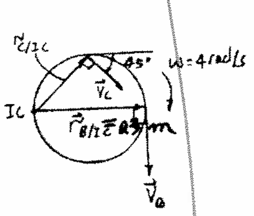
$$x = \frac{4}{3}r = 1.33r$$



$$\omega = \frac{2v}{1.33r} = 1.5\frac{v}{r}$$ **Ans**

***16-88.** At the instant shown, the disk is rotating at $\omega = 4$ rad/s. Determine the velocities of points A, B, and C.





The instantaneous center is located at point A. Hence, $v_A = 0$ **Ans**

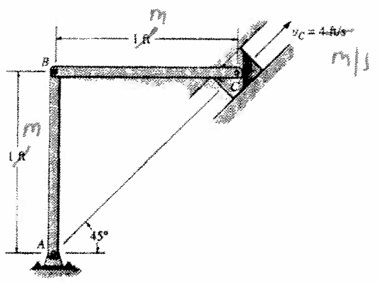
$r_{C/IC} = \sqrt{0.15^2 + 0.15^2} = 0.2121$ m $\quad r_{B/IC} = 0.3$ m

$v_B = \omega\, r_{B/IC} = 4(0.3) = 1.2$ m/s **Ans**

$v_C = \omega\, r_{C/IC} = 4(0.2121) = 0.849$ m/s $\searrow 45°$ **Ans**

47

16-~~89~~. The slider block C is moving 4 ~~ft/s~~ m/s up the incline. Determine the angular velocities of links AB and BC and the velocity of point B at the instant shown.



$v_C = \omega_{BC}(r_{C/IC})$

$4 = \omega_{BC}\sqrt{2}$

$\omega_{BC} = 2.83$ rad/s **Ans**

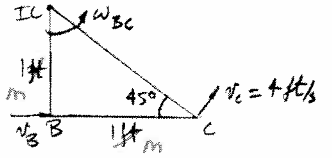
$v_B = 1(2.83) = 2.83$ ~~ft/s~~ m/s **Ans**

Thus,

$v_B = \omega_{AB} r_{AB}$

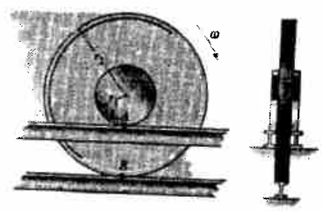
$2.83 = \omega_{AB}(1)$

$\omega_{AB} = 2.83$ rad/s **Ans**



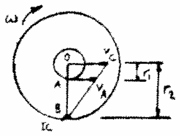
48

16-~~90~~. Show that if the rim of the wheel and its hub maintain contact with the three tracks as the wheel rolls, it is necessary that slipping occurs at the hub A if no slipping occurs at B. Under these conditions, what is the speed at A if the wheel has an angular velocity ω?

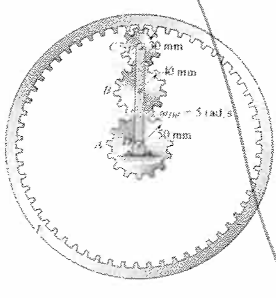


IC is at B.

$v_A = \omega(r_2 - r_1)$ → **Ans**



16–91. The epicyclic gear train is driven by the rotating link DE, which has an angular velocity $\omega_{DE} = 5$ rad/s. If the ring gear F is fixed, determine the angular velocities of gears A, B, and C.



$v_E = 0.$ $= 0.8$ m/s

$\omega_C = \frac{(}{0}$ 26.7 rad/s **Ans**

$v_P = (0$ $6.7) = 1.6$ m/s

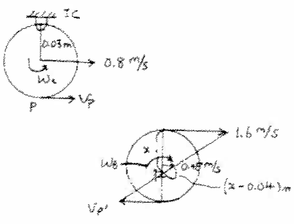
$\frac{1.6}{x} = \frac{}{x}$

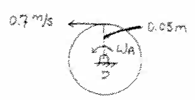
$x = 0.0$

$\omega_B = \frac{}{0}$ $= 28.75$ rad/s **Ans**

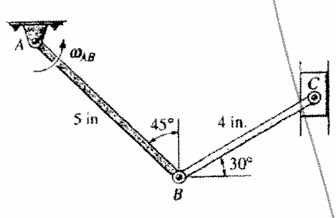
$v_{P'} = 28.75(0.08 - 0.05565) = 0.700$ m/s ←

$\omega_A = \frac{0.700}{0.05} = 14.0$ rad/s **Ans**





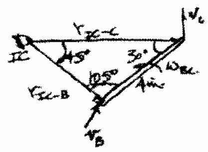
***16-92.** Determine the angular velocity of link AB at the instant shown if block C is moving upward at 12 in./s.



$$\frac{4}{\sin 45^\circ} = \frac{r_{IC-B}}{\sin 30^\circ} = \frac{r_{IC-C}}{\sin 105^\circ}$$

$r_{IC-C} = 5.464$ in.

$r_{IC-B} = 2.828$ in.



$v_C = \omega_{BC}(r_{IC-C})$

$12 = \omega_{BC}(5.464)$

$\omega_{BC} = 2.1962$ rad/s

$v_B = \omega_{BC}(r_{IC-B})$

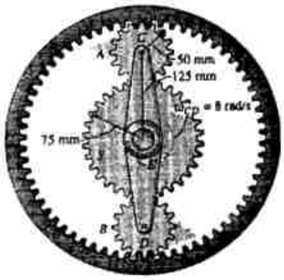
$= 2.1962(2.828) = 6.211$ in./s

$v_B = \omega_{AB} r_{AB}$

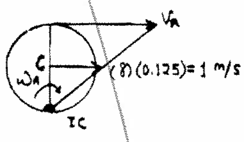
$6.211 = \omega_{AB}(5)$

$\omega_{AB} = 1.24$ rad/s **Ans**

16-93. In an automobile transmission the planet pinions A and B rotate on shafts that are mounted on the planet-pinion carrier CD. As shown, CD is attached to a shaft at E which is aligned with the center of the *fixed* sun gear S. This shaft is not attached to the sun gear. If CD is rotating at $\omega_{CD} = 8$ rad/s, determine the angular velocity of the ring gear R.



Pinion A :



$$\omega_A = \frac{1}{0.05} = 20 \text{ rad/s}$$

$v_R = (20)(0.1) = 2$ m/s

$$\omega_R = \frac{2}{(0.125 + 0.05)} = 11.4 \text{ rad/s} \quad \textbf{Ans}$$

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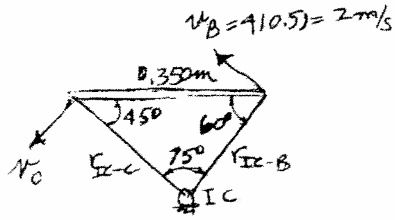
16-94. Knowing that the angular velocity of link AB is $\omega_{AB} = 4$ rad/s, determine the velocity of the collar at C and the angular velocity of link CB at the instant shown. Link CB is horizontal at this instant.



$$\frac{0.350}{\sin 75^\circ} = \frac{r_{IC-B}}{\sin 45^\circ} = \frac{r_{IC-C}}{\sin 60^\circ}$$

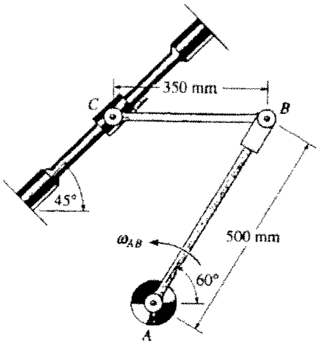
$r_{IC-B} = 0.2562$ m

$r_{IC-C} = 0.3138$ m

$$\omega_{CB} = \frac{2}{0.2562} = 7.8059 = 7.81 \text{ rad/s} \quad \textbf{Ans}$$

$v_C = 7.8059(0.3138) = 2.45$ m/s **Ans**

16–95. If the collar at C is moving downward to the left at $v_C = 8$ m/s, determine the angular velocity of link AB at the instant shown.



$$\frac{0.350}{\sin 75°} = \frac{r_{IC-B}}{\sin 45°} = \frac{r_{IC-C}}{\sin 60°}$$

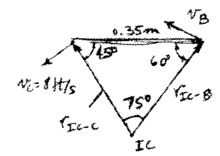
$r_{IC-B} = 0.2562$ m

$r_{IC-C} = 0.3138$ m

$$\omega_{CB} = \frac{8}{0.3138} = 25.494 \text{ rad/s}$$

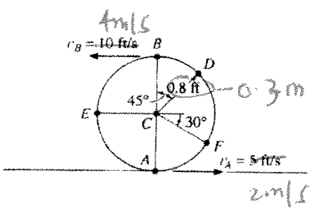
$v_B = 25.494(0.2562) = 6.5315$ m/s

$$\omega_{AB} = \frac{6.5315}{0.5} = 13.1 \text{ rad/s} \qquad \text{Ans}$$



51

***16–96.** Due to slipping, points A and B on the rim of the disk have the velocities shown. Determine the velocities of the center point C and point D at this instant.



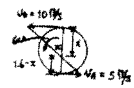
0.6

$$\frac{\cancel{1.6}-x}{\cancel{5}\ 1} = \frac{x}{\cancel{10}\ 2}$$

~~$5x = 16 - 10x$~~ $x = 1.2 - 2x$

$x = \cancel{1.06667 \text{ ft}}$ 0.4 m

$$\omega = \frac{10}{1.06667} = 9.375 \text{ rad/s} \qquad \frac{2}{0.4} = 5 \text{ rad/s}$$



$r_{IC-D} = \cancel{\sqrt{(0.2667)^2 + (0.8)^2 - 2(0.2667)(0.8)\cos 135°} = 1.006 \text{ ft}}$ $= \sqrt{(0.1)^2 + (0.3)^2 - 2(0.1)(0.3)\cos 135}$

$= \cancel{\ }$ m 0.377 m

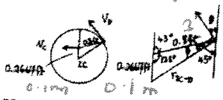
$$\frac{\sin\phi}{\cancel{0.2667}\ 0.1} = \frac{\sin 135°}{\cancel{1.006}\ 0.377}$$

$\phi = 10.80°$ ✓

$v_C = \cancel{0.2667(9.375) = 2.50 \text{ ft/s}}$ 0.1 5 0.5 m/s Ans

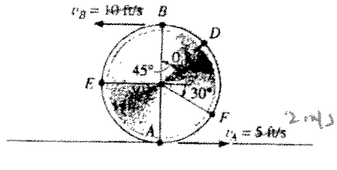
$v_D = \cancel{1.006(9.375) = 9.43 \text{ ft/s}}$ 0.377 5 1.585 m/s Ans

$\theta = 45° + 10.80° = 55.8°$ ✓



52

16–97. Due to slipping, points A and B on the rim of the disk have the velocities shown. Determine the velocities of the center point C and point E at this instant.



0.6

$$\frac{\cancel{1.6}-x}{\cancel{5}\ 1} = \frac{x}{\cancel{10}\ 2}$$

~~$5x = 16 - 10x$~~ $x = 1.2 - 2x$

$x = \cancel{1.06667 \text{ ft}}$ 0.4 m

$$\omega = \frac{\cancel{10}\ 2}{\cancel{1.06667}\ 0.4} = \cancel{9.375 \text{ rad/s}} \ 5 \text{ rad/s}$$

$v_C = \omega(r_{IC-C})$

5 0.4 0.3

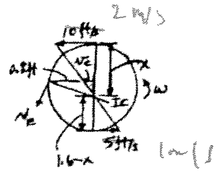
$= 9.375(1.06667 - 0.8)$

$= \cancel{2.50 \text{ ft/s}}$ 0.5 m/s Ans

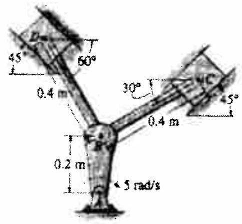
$v_E = \omega(r_{IC-E})$

$= \cancel{9.375\sqrt{(0.8)^2 + (0.26667)^2}}$ 5 $= 5\sqrt{(0.3)^2 + (0.1)^2}$

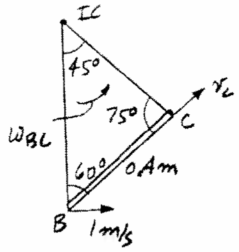
$= 7.91$ ft/s Ans $= 1.581$ m/s



16-98. The mechanism used in a marine engine consists of a single crank AB and two connecting rods BC and BD. Determine the velocity of the piston at C the instant the crank is in the position shown and has an angular velocity of 5 rad/s.



$v_B = 0.2(5) = 1 \text{ m/s} \rightarrow$



Member BC:

$$\frac{r_{C/IC}}{\sin 60^\circ} = \frac{0.4}{\sin 45^\circ}$$

$r_{C/IC} = 0.4899$ m

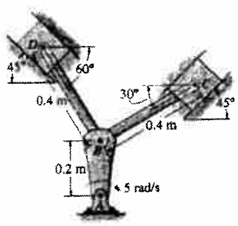
$$\frac{r_{B/IC}}{\sin 75^\circ} = \frac{0.4}{\sin 45^\circ}$$

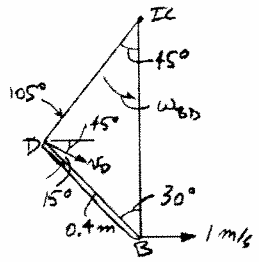
$r_{B/IC} = 0.5464$ m

$$\omega_{BC} = \frac{1}{0.5464} = 1.830 \text{ rad/s}$$

$v_C = 0.4899(1.830) = 0.897 \text{ m/s} \nearrow$ **Ans**

16-99. The mechanism used in a marine engine consists of a single crank AB and two connecting rods BC and BD. Determine the velocity of the piston at D the instant the crank is in the position shown and has an angular velocity of 5 rad/s.





$v_B = 0.2(5) = 1 \text{ m/s} \rightarrow$

Member BD:

$$\frac{r_{B/IC}}{\sin 105^\circ} = \frac{0.4}{\sin 45^\circ}$$

$r_{B/IC} = 0.54641$ m

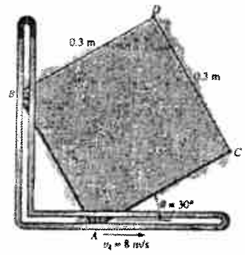
$$\frac{r_{D/IC}}{\sin 30^\circ} = \frac{0.4}{\sin 45^\circ}$$

$r_{D/IC} = 0.28284$ m

$$\omega_{BD} = \frac{1}{0.54641} = 1.830 \text{ rad/s}$$

$v_D = 1.830(0.28284) = 0.518 \text{ m/s} \searrow$ **Ans**

***16-100.** The square plate is confined within the slots at A and B. When $\theta = 30°$, point A is moving at $v_A = 8$ m/s. Determine the velocity of point C at this instant.



$r_{A/IC} = 0.3\cos 30° = 0.2598$ m

$$\omega = \frac{8}{0.2598} = 30.792 \text{ rad/s}$$

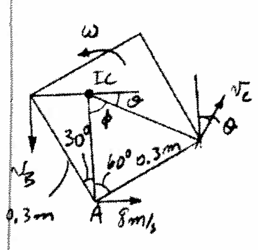
$r_{C/IC} = \sqrt{(0.2598)^2 + (0.3)^2 - 2(0.2598)(0.3)\cos 60°} = 0.2821$ m

$v_C = (0.2821)(30.792) = 8.69$ m/s **Ans**

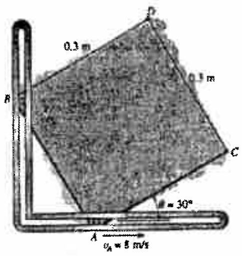
$$\frac{\sin\phi}{0.3} = \frac{\sin 60°}{0.2821}$$

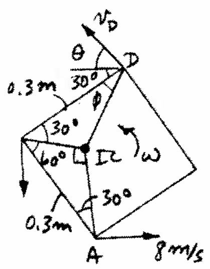
$\phi = 67.09°$

$\theta = 90° - 67.09° = 22.9°$ **Ans**



16-101. The square plate is confined within the slots at A and B. When $\theta = 30°$, point A is moving at $v_A = 8$ m/s. Determine the velocity of point D at this instant.





$r_{A/IC} = 0.3\cos 30° = 0.2598$ m

$$\omega = \frac{8}{0.2598} = 30.792 \text{ rad/s}$$

$r_{B/IC} = 0.3\sin 30° = 0.15$ m

$r_{D/IC} = \sqrt{(0.3)^2 + (0.15)^2 - 2(0.3)(0.15)\cos 30°} = 0.1859$ m

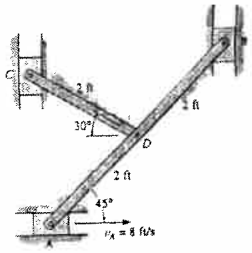
$v_D = (30.792)(0.1859) = 5.72$ m/s **Ans**

$$\frac{\sin\phi}{0.15} = \frac{\sin 30°}{0.1859}$$

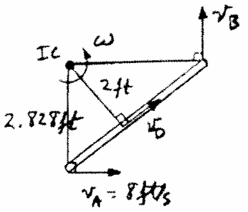
$\phi = 23.794°$

$\theta = 90° - 30° - 23.794° = 36.2°$ **Ans**

16-102. If the slider block A is moving to the right at $v_A = 8$ ft/s, determine the velocities of blocks B and C at the instant shown.



Bar AB :



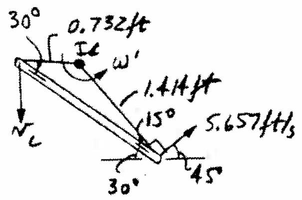
$r_{A/IC} = 4\cos 45° = 2.828$

$\omega = \dfrac{8}{2.828} = 2.83$ rad/s

$v_B = 2.83(2.828) = 8$ ft/s ↑ **Ans**

$v_D = 2(2.83) = 5.657$ ft/s

Bar CD :



$\dfrac{r_{D/IC}}{\sin 30°} = \dfrac{2}{\sin 135°}$

$r_{D/IC} = 1.414$ ft

$\dfrac{r_{C/IC}}{\sin 15°} = \dfrac{2}{\sin 135°}$

$r_{C/IC} = 0.7321$ ft

$\omega' = \dfrac{5.657}{1.414} = 4.00$ rad/s

$v_C = 0.7321(4.00) = 2.93$ ft/s ↓ **Ans**

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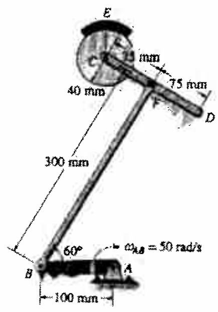
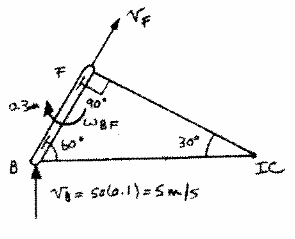
16-103. The crankshaft AB rotates at $\omega_{AB} = 50$ rad/s about the fixed axis through point A, and the disk at C is held fixed in its support at E. Determine the angular velocity of rod CD at the instant shown.





$r_{B/IC} = \dfrac{0.3}{\sin 30°} = 0.6$ m

$r_{F/IC} = \dfrac{0.3}{\tan 30°} = 0.5196$ m

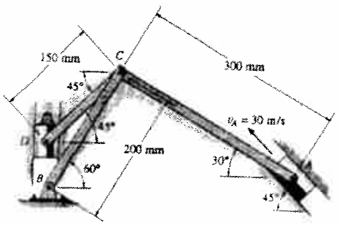
$\omega_{BF} = \dfrac{5}{0.6} = 8.333$ rad/s

$v_F = 8.333(0.5196) = 4.330$ m/s

Thus,

$\omega_{CD} = \dfrac{4.330}{0.075} = 57.7$ rad/s ↺ **Ans**

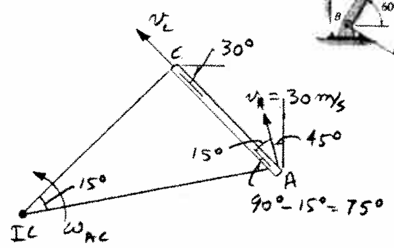
***16-104.** The mechanism shown is used in a riveting machine. It consists of a driving piston A, three members, and a riveter which is attached to the slider block D. Determine the velocity of D at the instant shown, when the piston at A is traveling at $v_A = 30$ m/s.



Link AC:

$$\omega_{AC} = \frac{v_A}{r_{A/IC}} = \frac{30}{\left(\frac{0.3}{\sin 15°}\right)} = 25.88 \text{ rad/s}$$

$$v_C = \omega_{AC} r_{C/IC} = (25.88)\left(\frac{0.3}{\tan 15°}\right) = 28.98 \text{ m/s}$$



Link DC:

$$\frac{r_{C/IC}}{\sin 45°} = \frac{0.15}{\sin 120°}$$

$r_{C/IC} = 0.1225$ m

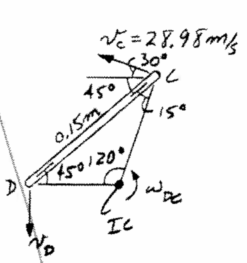
$$\frac{r_{D/IC}}{\sin 15°} = \frac{0.15}{\sin 120°}$$

$r_{D/IC} = 0.04483$ m

$$\omega_{DC} = \frac{v_C}{r_{C/IC}} = \frac{28.98}{0.1225} = 236.60 \text{ rad/s}$$

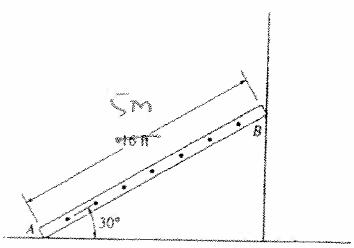
$v_D = \omega_{DC} r_{D/IC} = 236.60(0.04483)$

$v_D = 10.6$ m/s ↓ **Ans**



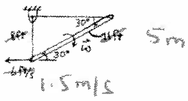
16-105. 54

At a given instant the bottom A of the ladder has an acceleration ~~$a_A = 4$ ft/s²~~ 1 m/s² and velocity ~~$v_A = 6$ ft/s~~ 1.5 m/s, both acting to the left. Determine the acceleration of the top of the ladder, B, and the ladder's angular acceleration at this same instant.



$$\omega = \frac{\cancel{6}\ 1.5}{\cancel{8}\ 2.5} = \cancel{0.75 \text{ rad/s}} \quad 0.6 \text{ rad/s}$$

2.5m

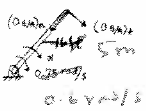


$a_B = a_A + (a_{B/A})_n + (a_{B/A})_t$

$$\underset{\downarrow}{a_B} = \underset{\leftarrow}{\cancel{4}\ 1} + \underset{30° \swarrow}{(0.\cancel{75}\ 6)^2(\cancel{16}\ 5)} + \underset{30° \searrow}{\alpha(\cancel{16}\ 5)}$$

$(\overset{+}{\leftarrow})$ $\quad 0 = \cancel{4}\ 1 + (0.\cancel{75}\ 6)^2(\cancel{16}\ 5)\cos 30° - \alpha(\cancel{16}\ 5)\sin 30°$

$(+\downarrow)$ $\quad a_B = 0 + (0.\cancel{75}\ 6)^2(\cancel{16}\ 5)\sin 30° + \alpha(\cancel{16}\ 5)\cos 30°$



Solving,

$\alpha = \cancel{1.47 \text{ rad/s}^2}$ 1.024 rad/s² **Ans**

$a_B = \cancel{24.9 \text{ ft/s}^2}$ ↓ 5.33 m/s² **Ans**

Also:

$\mathbf{a}_B = \mathbf{a}_A + \alpha \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$-a_B\mathbf{j} = -\cancel{4}\mathbf{i} + (\alpha\mathbf{k}) \times (\cancel{16}\ 5\cos 30°\mathbf{i} + \cancel{16}\ 5\sin 30°\mathbf{j}) - (0.\cancel{75}\ 6)^2(\cancel{16}\ 5\cos 30°\mathbf{i} + \cancel{16}\ 5\sin 30°\mathbf{j})$

$0 = -\cancel{4} - \cancel{8\alpha}\ 2.5\alpha - \cancel{7.794}\ 1.56$

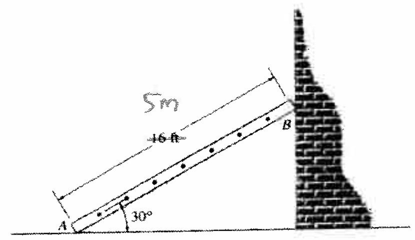
$-a_B = \cancel{13.856\alpha}\ 4.33\alpha - \cancel{4.5}\ 0.9$

$\alpha = \cancel{1.47 \text{ rad/s}^2}$ 1.02 rad/s² **Ans**

$a_B = \cancel{24.9 \text{ ft/s}^2 \downarrow}$ 5.33 m/s² **Ans**

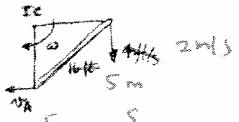
55 1m/s

16-~~106~~. At a given instant the top B of the ladder has an acceleration $a_B = \cancel{2\ \text{ft/s}^2}$ and a velocity of $v_B = \cancel{4\ \text{ft/s}}$ 2m/s, both acting downward. Determine the acceleration of the bottom A of the ladder, and the ladder's angular acceleration at this instant.



0.462 rad/s

$$\omega = \frac{\cancel{4}\ 2}{\cancel{16}\ 5\cos 30^\circ} = \cancel{0.288675\ \text{rad/s}}$$



$$\mathbf{a}_A = \mathbf{a}_B + \boldsymbol{\alpha} \times \mathbf{r}_{A/B} - \omega^2 \mathbf{r}_{A/B}$$

$$-a_A \mathbf{i} = -\cancel{2}\mathbf{j} + (\alpha\mathbf{k}) \times (-\cancel{16}\ 5\cos 30^\circ\mathbf{i} - \cancel{16}\ 5\sin 30^\circ\mathbf{j}) - (\cancel{0.288675}\ 0.462)^2(-\cancel{16}\ 5\cos 30^\circ\mathbf{i} - \cancel{16}\ 5\sin 30^\circ\mathbf{j})$$

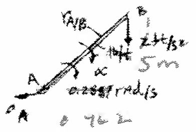
$$-a_A = \cancel{8}\ 2.5\,\alpha + \cancel{1.1547}\ 0.924$$

$$0 = -\cancel{2} - \cancel{13.856}\ 4.33\,\alpha + \cancel{0.6667}\ 0.534$$

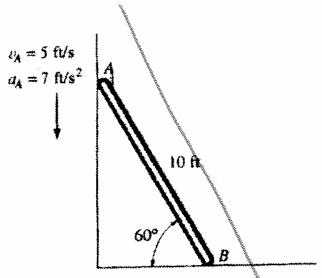
$$\alpha = -\cancel{0.0962}\ 0.107\ \text{rad/s}^2 = \cancel{0.0962}\ 0.107\ \text{rad/s}^2 \circlearrowright \qquad \textbf{Ans}$$

$$a_A = \cancel{-0.385\ \text{ft/s}^2 = 0.385\ \text{ft/s}^2 \rightarrow} \qquad \textbf{Ans}$$

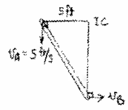
$$-0.657\ \text{m/s}^2 = 0.657\ \text{m/s}^2 \rightarrow$$



16-107. At a given instant the top end A of the bar has the velocity and acceleration shown. Determine the acceleration of the bottom B and the bar's angular acceleration at this instant.



$$\omega = \frac{5}{5} = 1.00\ \text{rad/s}$$



$$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$$

$$\underset{\rightarrow}{a_B} = \underset{\downarrow}{7} + \underset{\nwarrow 30^\circ}{10} + \underset{\angle 30^\circ}{\alpha(10)}$$

$$(\overset{+}{\rightarrow}) \qquad a_B = 0 - 10\sin 30^\circ + \alpha(10)\cos 30^\circ$$

$$(+\uparrow) \qquad 0 = -7 + 10\cos 30^\circ + \alpha(10)\sin 30^\circ$$

$$\alpha = -0.3321\ \text{rad/s}^2 = 0.332\ \text{rad/s}^2 \qquad \textbf{Ans}$$

$$a_B = -7.875\ \text{ft/s}^2 = 7.88\ \text{ft/s}^2 \leftarrow \qquad \textbf{Ans}$$

Also :

$$\mathbf{a}_B = \mathbf{a}_A - \omega^2 \mathbf{r}_{B/A} + \boldsymbol{\alpha} \times \mathbf{r}_{B/A}$$

$$a_B\mathbf{i} = -7\mathbf{j} - (1)^2(10\cos 60^\circ\mathbf{i} - 10\sin 60^\circ\mathbf{j}) + (\alpha\mathbf{k}) \times (10\cos 60^\circ\mathbf{i} - 10\sin 60^\circ\mathbf{j})$$

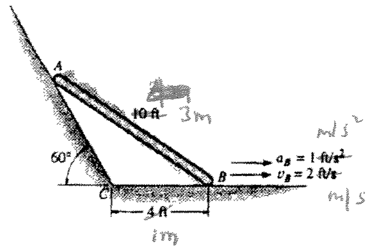
$$\overset{+}{\rightarrow} \qquad a_B = -10\cos 60^\circ + \alpha(10\sin 60^\circ)$$

$$+\uparrow \qquad 0 = -7 + 10\sin 60^\circ + \alpha(10\cos 60^\circ)$$

$$\alpha = -0.3321\ \text{rad/s}^2 = 0.332\ \text{rad/s}^2 \qquad \textbf{Ans}$$

$$a_B = -7.875\ \text{ft/s}^2 = 7.88\ \text{ft/s}^2 \leftarrow \qquad \textbf{Ans}$$

•16-~~108~~ 56. The 10-ft rod slides down the inclined plane, such that when it is at B it has the motion shown. Determine the velocity and acceleration of A at this instant.



$(3)^2 = (1)^2 + (AC)^2 - 2(AC)(1)\cos 120$

$\cancel{(10)^2 = (4)^2 + (AC)^2 - 2(AC)(4)\cos 120°}$

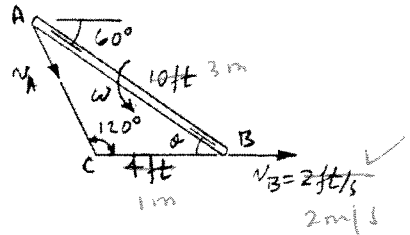
$(AC)^2 + AC - 8 = 0$

$\cancel{(AC)^2 + 4(AC) - 84 = 0}$

Solving for the positive root:

$AC = \cancel{7.381\text{ ft}}$ 2.37 m

$$\frac{\sin\theta}{\cancel{7.381}\ 2.37} = \frac{\sin 120°}{\cancel{10}\ 3} \qquad \theta = \cancel{39.732°}\ 43.17°$$



$\mathbf{v}_A = \mathbf{v}_B + \omega \times \mathbf{r}_{A/B}$

$v_A\cos 60°\mathbf{i} - v_A\sin 60°\mathbf{j} = 2\mathbf{i} + \omega\mathbf{k} \times (-\cancel{10}\,3\cos\cancel{39.732°}\,43.17°\,\mathbf{i} + \cancel{10}\,3\sin\cancel{39.732°}\,43.17°\,\mathbf{j})$

$(\overset{+}{\rightarrow}) \qquad 0.5v_A = 2 - \cancel{6.39199\omega}\ 2.052\omega$

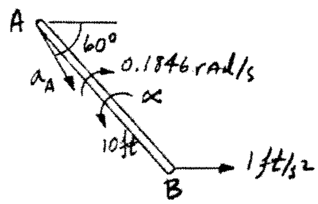
$(+\uparrow) \qquad -0.86603v_A = \cancel{-7.6904\omega}\ 2.188\omega$

Solving:

$\omega = 0.\cancel{1846\text{ rad/s}}$ 0.60 rad/s

$v_A = 1.\cancel{64\text{ ft/s}}$ 1.52 m/s **Ans**

$\mathbf{a}_A = \mathbf{a}_B + \alpha \times \mathbf{r}_{A/B} - \omega^2\mathbf{r}_{A/B}$



$a_A\cos 60°\mathbf{i} - a_A\sin 60°\mathbf{j} = 1\mathbf{i} + (\alpha\mathbf{k}) \times (-\cancel{10}\,3\cos\cancel{39.732°}\,43.17°\,\mathbf{i} + \cancel{10}\,3\sin\cancel{39.732°}\,43.17°\,\mathbf{j})$

$\qquad - (\cancel{0.1846}\ 0.60)^2(-\cancel{10}\,3\cos\cancel{39.732°}\,43.17°\,\mathbf{i} + \cancel{10}\,3\sin\cancel{39.732°}\,43.17°\,\mathbf{j})$

$(\overset{+}{\rightarrow}) \qquad 0.5a_A = 1 - \cancel{6.3920\alpha}\ 2.052\alpha + \cancel{0.2621}\ 0.788$

$(+\uparrow) \qquad -0.86603a_A = \cancel{-7.69042\alpha}\ 2.188\alpha - 0.\cancel{21791}\ 0.739$

Solving:

$a_A = \cancel{1.18\text{ ft/s}^2}$ 3.52 m/s² **Ans**

$\alpha = \cancel{0.105\text{ rad/s}^2}$ 1.73 rad/s²

$AC = \dfrac{-1 \pm \sqrt{1+32}}{2}$

$V_a = 4 - 4.104\omega$

$-0.866(4 - 4.104\omega) = 2.188\omega$

$4 - 4.104\omega = 2.527\omega$

$a_A = 3.576 - 4.104\alpha$

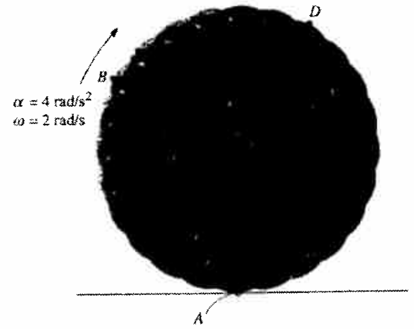
$-.866(3.576 - 4.104\alpha) = 2.188\alpha - 0.739$

$3.576 - 4.104\alpha = -2.526\alpha + 0.853$

$\alpha_A = 1.73$

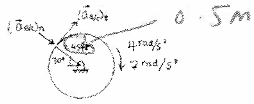
57

16-109. The wheel is moving to the right such that it has an angular velocity $\omega = 2$ rad/s and angular acceleration $\alpha = 4$ rad/s² at the instant shown. If it does not slip at A, determine the acceleration of point B.



Since no slipping

$a_C = \alpha r = 4(\cancel{1.45}\ 0.5) = \cancel{5.80 \text{ ft/s}^2}\ 2 \text{ m/s}^2$



$\mathbf{a}_B = \mathbf{a}_C + \mathbf{a}_{B/C}$

$\mathbf{a}_B = \underset{\rightarrow}{\cancel{5.80}\ 2} + \underset{\searrow 30°}{(2)^2(\cancel{1.45}\ 0.5)} + \underset{\nearrow 30°}{4(\cancel{1.45}\ 1.5)}$

$(\xrightarrow{+})\quad (a_B)_x = \cancel{5.80}\ 2 + \cancel{5.02}\ 2 + \cancel{2.9}\ 2 = \cancel{13.72}\ 6$

$(+\uparrow)\quad (a_B)_y = 0 - \cancel{2.9}\ 2 + \cancel{5.02}\ 2 = \cancel{2.12}\ 0$

$a_B = \sqrt{(\cancel{13.72}\ 6)^2 + (\cancel{2.12}\ 0)^2} = \cancel{13.9 \text{ ft/s}^2}\ 6 \text{ m/s}$ **Ans**

$\theta = \tan^{-1}\left(\dfrac{\cancel{2.123}\ 0}{\cancel{13.72}\ 6}\right) = \cancel{8.80°}\ 0$ **Ans**

Also:

$\mathbf{a}_B = \mathbf{a}_C + \alpha \times \mathbf{r}_{B/C} - \omega^2 \mathbf{r}_{B/C}$

$\mathbf{a}_B = \cancel{5.80}\ 2\,\mathbf{i} + (-4\mathbf{k}) \times (\cancel{-1.45}\ {-0.5}\cos 30°\mathbf{i} + \cancel{1.45}\ 0.5\sin 30°\mathbf{j}) - (2)^2(\cancel{-1.45}\ {-0.5}\cos 30°\mathbf{i} + \cancel{1.45}\ 0.5\sin 30°\mathbf{j})$

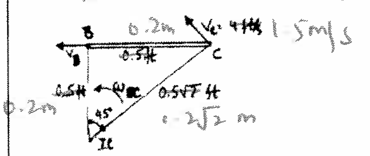
$\mathbf{a}_B = \{\cancel{13.72}\ 6\,\mathbf{i} + \cancel{2.123}\ 0\,\mathbf{j}\}\ \cancel{\text{ft}}\ \text{m/s}^2$

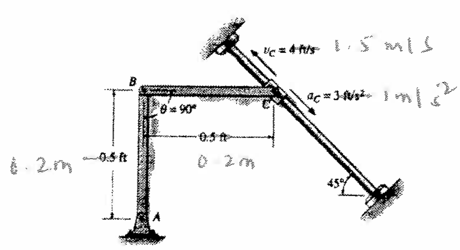
$a_B = \sqrt{(\cancel{13.72}\ 6)^2 + (\cancel{2.123}\ 0)^2} = \cancel{13.9 \text{ ft}}\ 6 \text{ m/s}^2$ **Ans**

$\theta = \tan^{-1}\left(\dfrac{\cancel{2.123}\ 0}{\cancel{13.72}\ 6}\right) = \cancel{8.80°}\ 0$ **Ans**

58

16-110. Determine the angular acceleration of link AB at the instant $\theta = 90°$ if the collar C has a velocity of $v_C = \cancel{4 \text{ ft/s}}$ 1.5 m/s and deceleration of $a_C = \cancel{3 \text{ ft/s}^2}$ 1 m/s² as shown.





$\omega_{BC} = \dfrac{v_C}{r_{C/IC}} = \dfrac{\cancel{4}\ 1.5}{\cancel{0.5\sqrt{2}}\ 0.2} = \cancel{5.657 \text{ rad/s}}$ 5.30 rad/s

$v_B = \omega_{BC} r_{B/IC} = \cancel{5.657}\ 5.3\,(\cancel{0.5}\ 0.2) = \cancel{2.828 \text{ ft/s}}$ 1.06 m/s

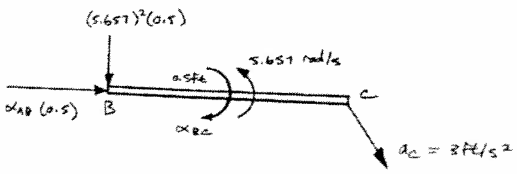
$\omega_{AB} = \dfrac{v_B}{r_{B/A}} = \dfrac{\cancel{2.828}\ 1.06}{\cancel{0.5}\ 0.2} = \cancel{5.657 \text{ rad/s}}$ 5.30 rad/s

$(\mathbf{a}_B)_t + (\mathbf{a}_B)_n = \mathbf{a}_C + \alpha \times \mathbf{r}_{B/C} - \omega^2 \mathbf{r}_{B/C}$

$\alpha_{AB}(\cancel{0.5}\ 0.2)\mathbf{i} - (\cancel{5.657}\ 5.30)^2(\cancel{0.5}\ 0.2)\mathbf{j} = \cancel{3}\ 1\cos 45°\mathbf{i} - \cancel{3}\ 1\sin 45°\mathbf{j} + (-\alpha_{BC}\mathbf{k}) \times (-0.\cancel{5}2\,\mathbf{i}) - (\cancel{5.657}\ 5.30)^2(-0.\cancel{5}2\,\mathbf{i})$

$(\xrightarrow{+})\quad \alpha_{AB}(\cancel{0.5}\ 0.2) = \cancel{3}\ 1\cos 45° + (\cancel{5.657}\ 5.30)^2(0.\cancel{5}2)$

$(+\uparrow)\quad -(\cancel{5.657}\ 5.30)^2(\cancel{0.5}\ 0.2) = -\cancel{3}\ 1\sin 45° - \alpha_{BC}(0.\cancel{5}2)$

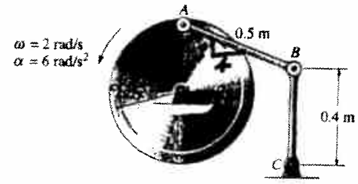


Solving,

$\alpha_{AB} = \cancel{36.2}$ 31.63 rad/s² **Ans**

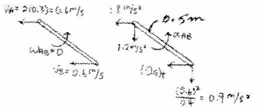
$\alpha_{BC} = \cancel{27.8 \text{ rad/s}^2}$ 24.55 rad/s²

16-111. The flywheel rotates with an angular velocity $\omega = 2$ rad/s and an angular acceleration $\alpha = 6$ rad/s^2. Determine the angular acceleration of links AB and BC at this instant.



$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$

$(a_B)_t + 0.9 = 1.8 + 1.2 + \alpha_{AB}(0.5)$



$(\overset{+}{\leftarrow})\quad (a_B)_t = 1.8 - \frac{3}{5}(\alpha_{AB})(0.5)$

$(+\downarrow)\quad 0.9 = 1.2 - \frac{4}{5}(\alpha_{AB})(0.5)$

$\alpha_{AB} = 0.75$ rad/s^2 ↺ **Ans**

$(a_B)_t = 1.575$ m/s^2

$\alpha_{BC} = \frac{1.575}{0.4} = 3.94$ rad/s^2 ↺ **Ans**

Also:

$\mathbf{a}_B = \mathbf{a}_A + \boldsymbol{\alpha}_{AB} \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$-(a_B)_t\mathbf{i} - \frac{(0.6)^2}{0.4}\mathbf{j} = -6(0.3)\mathbf{i} - (2)^2(0.3)\mathbf{j} + (\alpha_{AB}\mathbf{k}) \times (0.4\mathbf{i} - 0.3\mathbf{j}) - 0$

$-(a_B)_t = -1.8 + 0.3\alpha_{AB}$

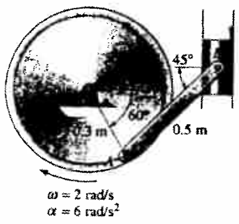
$-0.9 = -1.2 + 0.4\alpha_{AB}$

$\alpha_{AB} = 0.75$ rad/s^2 ↺ **Ans**

$(a_B)_t = 1.575$ m/s^2

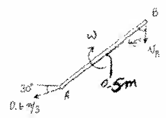
$\alpha_{BC} = \frac{1.575}{0.4} = 3.94$ rad/s^2 ↺ **Ans**

***16-112.** At a given instant the wheel is rotating with the angular velocity and angular acceleration shown. Determine the acceleration of block B at this instant.



$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{B/A}$

$v_B = 0.6 + \omega(0.5)$



$\overset{+}{\rightarrow}\quad 0 = -0.6\cos 30° + \omega(0.5)\cos 45°$

$\omega = 1.470$ rad/s

$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$

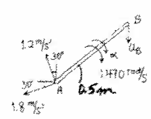
$a_B = 1.8 + 1.2 + (1.470)^2(0.5) + \alpha(0.5)$

$(\overset{+}{\rightarrow})\quad 0 = -1.8\cos 30° - 1.2\sin 30° - 1.08\sin 45° + \alpha(0.5)\cos 45°$

$(+\downarrow)\quad a_B = 1.8\sin 30° - 1.2\cos 30° + 1.08\sin 45° + \alpha(0.5)\sin 45°$

$\alpha = 8.266$ rad/s^2

$a_B = 3.55$ m/s^2 **Ans**



Also:

$\mathbf{v}_B = \mathbf{v}_A + \boldsymbol{\omega} \times \mathbf{r}_{B/A}$

$-v_B\mathbf{i} = (-0.6\cos 30°\mathbf{i} - 0.6\sin 30°\mathbf{j}) + (-\omega\mathbf{k}) \times (0.5\cos 45°\mathbf{i} + 0.5\sin 45°\mathbf{j})$

$0 = -0.6\cos 30° + \omega(0.5\sin 45°)$

$\omega = 1.470$ rad/s

$\mathbf{a}_B = \mathbf{a}_A - \omega^2\mathbf{r}_{B/A} + \boldsymbol{\alpha} \times \mathbf{r}_{B/A}$

$-a_B\mathbf{j} = (-1.2\sin 30°\mathbf{i} + 1.2\cos 30°\mathbf{j}) + (-1.8\cos 30°\mathbf{i} - 1.8\sin 30°\mathbf{j})$
$+ (-\alpha\mathbf{k}) \times (0.5\cos 45°\mathbf{i} + 0.5\sin 45°\mathbf{j})$

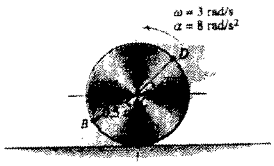
$0 = -1.2\sin 30° - 1.8\cos 30° - (1.470)^2(0.5\cos 45°) + \alpha(0.5\sin 45°)$

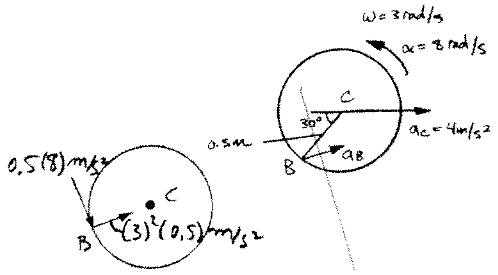
$-a_B = 1.2\cos 30° - 1.8\sin 30° - (1.470)^2(0.5\sin 45°) - \alpha(0.5\sin 45°)$

$\alpha = 8.266$ rad/s

$a_B = 3.55$ m/s^2 **Ans**

16-113. The disk is moving to the left such that it has an angular acceleration $\alpha = 8\ \text{rad/s}^2$ and angular velocity $\omega = 3$ rad/s at the instant shown. If it does not slip at A, determine the acceleration of point B.





$a_C = 0.5(8) = 4\ \text{m/s}^2$

$\mathbf{a}_B = \mathbf{a}_C + \mathbf{a}_{B/C}$

$$\mathbf{a}_B = \begin{bmatrix} 4 \\ \leftarrow \end{bmatrix} + \begin{bmatrix} (3)^2(0.5) \\ \measuredangle 30° \end{bmatrix} + \begin{bmatrix} (0.5)(8) \\ \measuredangle 30° \end{bmatrix}$$

$(\overset{+}{\rightarrow})\quad (a_B)_x = -4 + 4.5\cos 30° + 4\sin 30° = 1.897\ \text{m/s}^2$

$(+\uparrow)\quad (a_B)_y = 0 + 4.5\sin 30° - 4\cos 30° = -1.214\ \text{m/s}^2$

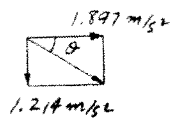
$a_B = \sqrt{(1.897)^2 + (-1.214)^2} = 2.25\ \text{m/s}^2$ **Ans**

$\theta = \tan^{-1}\left(\frac{1.214}{1.897}\right) = 32.6°$ ↘ **Ans**

Also,

$\mathbf{a}_B = \mathbf{a}_C + \boldsymbol{\alpha} \times \mathbf{r}_{B/C} - \omega^2 \mathbf{r}_{B/C}$

$(a_B)_x\mathbf{i} + (a_B)_y\mathbf{j} = -4\mathbf{i} + (8\mathbf{k}) \times (-0.5\cos 30°\mathbf{i} - 0.5\sin 30°\mathbf{j}) - (3)^2(-0.5\cos 30°\mathbf{i} - 0.5\sin 30°\mathbf{j})$



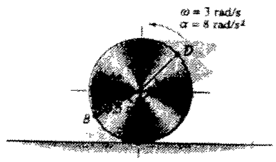
$(\overset{+}{\rightarrow})\quad (a_B)_x = -4 + 8(0.5\sin 30°) + (3)^2(0.5\cos 30°) = 1.897\ \text{m/s}^2$

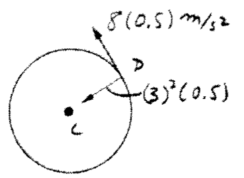
$(+\uparrow)\quad (a_B)_y = 0 - 8(0.5\cos 30°) + (3)^2(0.5\sin 30°) = -1.214\ \text{m/s}^2$

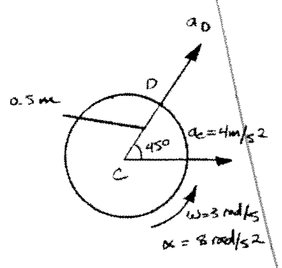
$\theta = \tan^{-1}\left(\frac{1.214}{1.897}\right) = 32.6°$ ↘ **Ans**

$a_B = \sqrt{(1.897)^2 + (-1.214)^2} = 2.25\ \text{m/s}^2$ **Ans**

16-114. The disk is moving to the left such that it has an angular acceleration $\alpha = 8\ \text{rad/s}^2$ and angular velocity $\omega = 3\ \text{rad/s}$ at the instant shown. If it does not slip at A, determine the acceleration of point D.







$a_C = 0.5(8) = 4\ \text{m/s}^2$

$\mathbf{a}_D = \mathbf{a}_C + \mathbf{a}_{D/C}$

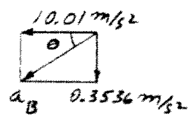
$$\mathbf{a}_D = \left[\underset{\leftarrow}{4}\right] + \left[\underset{\swarrow 45^\circ}{(3)^2(0.5)}\right] + \left[\underset{45^\circ \nwarrow}{8(0.5)}\right]$$

$(\overset{+}{\rightarrow})\quad (a_D)_x = -4 - 4.5\sin 45^\circ - 4\cos 45^\circ = -10.01\ \text{m/s}^2$

$(+\uparrow)\quad (a_D)_y = 0 - 4.5\cos 45^\circ + 4\sin 45^\circ = -0.3536\ \text{m/s}^2$

$$\theta = \tan^{-1}\left(\frac{0.3536}{10.01}\right) = 2.02^\circ \qquad \textbf{Ans}$$

$$a_D = \sqrt{(-10.01)^2 + (-0.3536)^2} = 10.0\ \text{m/s}^2 \ \swarrow \qquad \textbf{Ans}$$



Also,

$\mathbf{a}_D = \mathbf{a}_C + \alpha \times \mathbf{r}_{D/C} - \omega^2 \mathbf{r}_{D/C}$

$(a_D)_x\,\mathbf{i} + (a_D)_y\,\mathbf{j} = -4\mathbf{i} + (8\mathbf{k}) \times (0.5\cos 45^\circ\mathbf{i} + 0.5\sin 45^\circ\mathbf{j}) - (3)^2(0.5\cos 45^\circ\mathbf{i} + 0.5\sin 45^\circ\mathbf{j})$

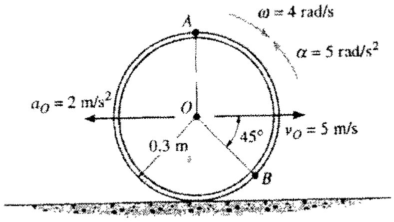
$(\overset{+}{\rightarrow})\quad (a_D)_x = -4 - 8(0.5\sin 45^\circ) - (3)^2(0.5\cos 45^\circ) = -10.01\ \text{m/s}^2$

$(+\uparrow)\quad (a_D)_y = +8(0.5\cos 45^\circ) - (3)^2(0.5\sin 45^\circ) = -0.3536\ \text{m/s}^2$

$$\theta = \tan^{-1}\left(\frac{0.3536}{10.01}\right) = 2.02^\circ \ \swarrow \qquad \textbf{Ans}$$

$$a_D = \sqrt{(-10.01)^2 + (-0.3536)^2} = 10.0\ \text{m/s}^2 \qquad \textbf{Ans}$$

16-115. The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4$ rad/s and an angular acceleration $\alpha = 5$ rad/s^2. Also, its center has a velocity $v_O = 5$ m/s and a deceleration $a_O = 2$ m/s^2. Determine the acceleration of point A at this instant.



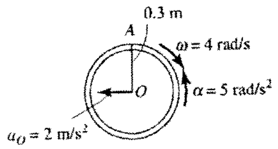
$\mathbf{a}_A = \mathbf{a}_O + \mathbf{a}_{A/O}$

$$\mathbf{a}_A = \left[\underset{\leftarrow}{2}\right] + \left[\underset{\downarrow}{(4)^2(0.3)}\right] + \left[\underset{\longleftarrow}{5(0.3)}\right]$$

$$\mathbf{a}_A = \left[\underset{\leftarrow}{3.5}\right] + \left[\underset{\downarrow}{4.8}\right]$$

$a_A = 5.94$ m/s^2 **Ans**

$$\theta = \tan^{-1}\left(\frac{4.8}{3.5}\right) = 53.9^\circ$$ **Ans**



Also:

$\mathbf{a}_A = \mathbf{a}_O - \omega^2\mathbf{r}_{A/O} + \boldsymbol{\alpha} \times \mathbf{r}_{A/O}$

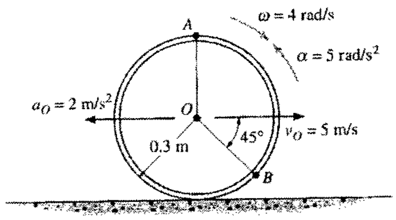
$\mathbf{a}_A = -2\mathbf{i} - (4)^2(0.3\mathbf{j}) + 5\mathbf{k} \times (0.3\mathbf{j})$

$\mathbf{a}_A = \{-3.5\mathbf{i} - 4.8\mathbf{j}\}$ m/s^2

$a_A = 5.94$ m/s^2 **Ans**

$$\theta = \tan^{-1}\left(\frac{4.8}{3.5}\right) = 53.9^\circ$$ **Ans**

***16-116.** The hoop is cast on the rough surface such that it has an angular velocity $\omega = 4$ rad/s and an angular acceleration $\alpha = 5$ rad/s^2. Also, its center has a velocity of $v_O = 5$ m/s and a deceleration $a_O = 2$ m/s^2. Determine the acceleration of point B at this instant.



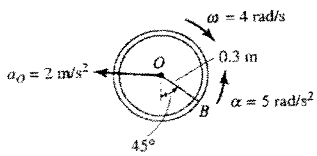
$\mathbf{a}_B = \mathbf{a}_O + \mathbf{a}_{B/O}$

$$\mathbf{a}_B = \left[\underset{\leftarrow}{2}\right] + \left[\underset{\angle}{5(0.3)}\right] + \left[\underset{\searrow}{(4)^2(0.3)}\right]$$

$$\mathbf{a}_B = \left[\underset{\leftarrow}{4.333}\right] + \left[\underset{\uparrow}{4.455}\right]$$

$a_B = 6.21$ m/s^2 **Ans**

$$\theta = \tan^{-1}\left(\frac{4.455}{4.333}\right) = 45.8^\circ$$ **Ans**



Also:

$\mathbf{a}_B = \mathbf{a}_O + \boldsymbol{\alpha} \times \mathbf{r}_{B/O} - \omega^2\mathbf{r}_{B/O}$

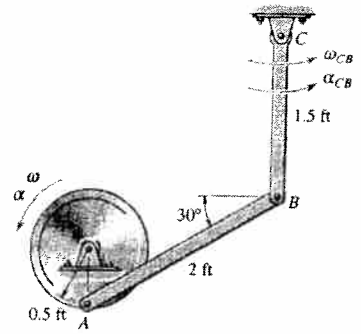
$\mathbf{a}_B = -2\mathbf{i} + 5\mathbf{k} \times (0.3\cos 45^\circ\mathbf{i} - 0.3\sin 45^\circ\mathbf{j}) - (4)^2(0.3\cos 45^\circ\mathbf{i} - 0.3\sin 45^\circ\mathbf{j})$

$\mathbf{a}_B = \{-4.333\mathbf{i} + 4.455\mathbf{j}\}$ m/s^2

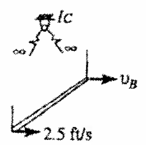
$a_B = 6.21$ m/s^2 **Ans**

$$\theta = \tan^{-1}\left(\frac{4.455}{4.333}\right) = 45.8^\circ$$ **Ans**

16-117. The disk rotates with an angular velocity $\omega = 5\ \text{rad/s}$ and an angular acceleration $\alpha = 6\ \text{rad/s}^2$. Determine the angular acceleration of link CB at this instant.



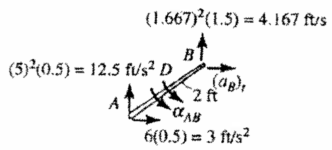
The IC is at ∞. Thus



$\omega = 0$

$v_A = v_B = 2.5$ ft/s

$\omega_{BC} = \dfrac{2.5}{1.5} = 1.667$ rad/s



$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$

$$\underset{\rightarrow}{(a_B)_t} + \underset{\uparrow}{4.167} = \underset{\rightarrow}{3} + \underset{\uparrow}{12.5} + \underset{\searrow 30^\circ}{2\alpha_{AB}}$$

$(\overset{+}{\leftarrow})\quad (a_B)_t = 3 - 2\alpha_{AB}\sin 30^\circ$

$(+\uparrow)\quad 4.167 = 12.5 + 2\alpha_{AB}\cos 30^\circ$

$\alpha_{AB} = -4.81\ \text{rad/s}^2 = 4.81\ \text{rad/s}^2$

$(a_B)_t = 7.81\ \text{ft/s}^2$

$\alpha_{BC} = \dfrac{7.81}{1.5} = 5.21\ \text{rad/s}^2$ **Ans**

Also:

$\mathbf{a}_B = \mathbf{a}_A + \alpha_{AB} \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$(a_B)_t\mathbf{i} + 4.167\mathbf{j} = (3\mathbf{i} + 12.5\mathbf{j}) - 0 + (\alpha_{AB}\mathbf{k}) \times (2\cos 30^\circ\mathbf{i} + 2\sin 30^\circ\mathbf{j})$

$(a_B)_t = 3 - 2\alpha_{AB}\sin 30^\circ$

$4.167 = 12.5 + 2\alpha_{AB}\cos 30^\circ$

$\alpha_{AB} = -4.81\ \text{rad/s}^2 = 4.81\ \text{rad/s}^2$

$(a_B)_t = 7.81\ \text{ft/s}^2$

$\alpha_{BC} = \dfrac{7.81}{1.5} = 5.21\ \text{rad/s}^2$ **Ans**

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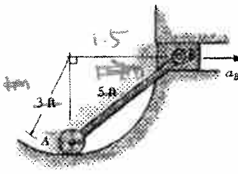
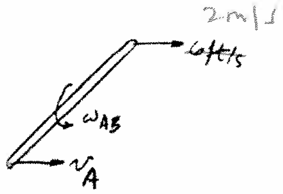
16-118. At a given instant the slider block B is moving to the right with the motion shown. Determine the angular acceleration of link AB and the acceleration of point A at this instant.



$\omega_{AB} = \frac{v_B}{r_{B/IC}} = \frac{\cancel{6}\ 2}{\infty} = 0 \qquad v_A = v_B = \cancel{6\text{ ft/s}}$ 2 m/s

$\omega_{AC} = \frac{v_A}{r_{AC}} = \frac{\cancel{6}}{\cancel{3}} = \cancel{2\text{ rad/s}}$ $\frac{2}{0.9} = 2.22$ rad/s



$\mathbf{a}_B = \{2\mathbf{i}\}$ ft/s² 0.9 m $\qquad \mathbf{a}_A = (a_A)_x\,\mathbf{i} + \cancel{(2)^2(3)}\mathbf{j} = (a_A)_x\,\mathbf{i} + \cancel{12}\mathbf{j}$ 0.324

$(2.22)^2(0.9)\mathbf{j} = (a_A)_x + 4.44\mathbf{j}$

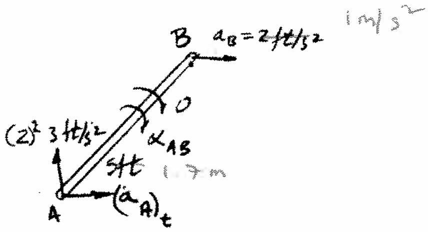
$\alpha_{AB} = -\alpha_{AB}\mathbf{k} \qquad \mathbf{r}_{B/A} = \{\cancel{4}\mathbf{i} + \cancel{3}\mathbf{j}\}$ ~~ft~~ m (1.2, 0.9)

$\mathbf{a}_B = \mathbf{a}_A + \alpha_{AB} \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$\cancel{2}\mathbf{i} = \left[(a_A)_x\,\mathbf{i} + \cancel{12}\mathbf{j}\right] + (-\alpha_{AB}\mathbf{k}) \times (\cancel{4}\mathbf{i} + \cancel{3}\mathbf{j}) - 0$ (4.44; 1.2, 0.9)

$(\xrightarrow{+}) \qquad \cancel{2} = (a_A)_x + \cancel{3(3)}$ $0.9\,\alpha_{AB}$ $\qquad (a_A)_x = \cancel{-7\text{ ft/s}^2}$ -2.33 m/s²

$(+\uparrow) \qquad 0 = \cancel{12} - \cancel{4}\alpha_{AB}$ (4.44; 1.2) $\qquad \alpha_{AB} = \cancel{3\text{ rad/s}^2}$ 3.7 rad/s² **Ans**



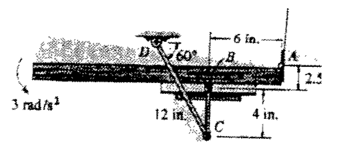
$\mathbf{a}_A = \cancel{\{-7\mathbf{i} + 12\mathbf{j}\}\text{ ft/s}^2}$ $(-2.33\mathbf{i} + 4.44\mathbf{j})$ m/s²

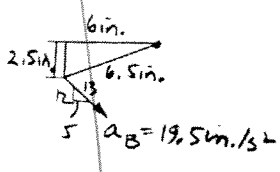
$a_A = \cancel{\sqrt{(-7)^2 + 12^2} = 13.9\text{ ft/s}^2}$ **Ans** $\sqrt{(-2.33)^2 + (4.44)^2} = 5.01$ m/s²

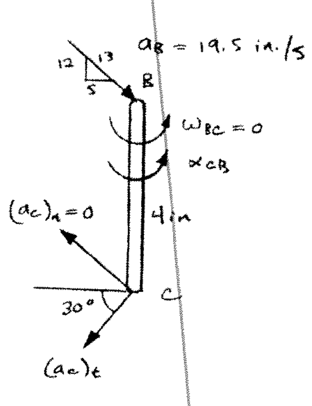
$\theta = \tan^{-1}\frac{12}{7} = 59.7°$ **Ans**

$= \tan^{-1}\left(\frac{4.44}{2.33}\right) = 62.3°$

16-119. The closure is manufactured by the LCN Company and is used to control the restricted motion of a heavy door. If the door to which is it connected has an angular acceleration of 3 rad/s^2, determine the angular acceleration of links BC and CD. Originally the door is not rotating but is hinged at A.







$\mathbf{a}_B = (\mathbf{a}_B)_t + (\mathbf{a}_B)_n$

$(a_B)_t = \alpha r_{AB} = 3(6.5) = 19.5 \text{ in./s}^2$

$(a_B)_n = \omega^2 r_{AB} = 0^2(6.5) = 0$

$(a_C)_n = \omega^2 r_{DC} = 0(12) = 0$

$\mathbf{a}_C = \mathbf{a}_B + \alpha \times \mathbf{r}_{C/B} - \omega^2 \mathbf{r}_{C/B}$

$-(a_C)_t \cos 30°\mathbf{i} - (a_C)_t \sin 30°\mathbf{j} = 19.5\left(\frac{5}{13}\right)\mathbf{i} - 19.5\left(\frac{12}{13}\right)\mathbf{j} + (\alpha_{CB}\mathbf{k}) \times (-4\mathbf{j}) - (0)^2(-4\mathbf{j})$

$(\xrightarrow{+})$ $\quad -0.8660(a_C)_t = 7.5 + 4\alpha_{CB}$

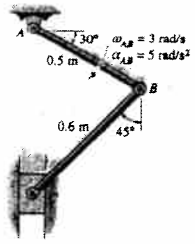
$(+\uparrow)$ $\quad -0.5(a_C)_t = -18$

Solving :

$(a_C)_t = 36 \text{ in./s}^2$

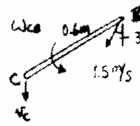
$\alpha_{CB} = -9.67 \text{ rad/s}^2 = 9.67 \text{ rad/s}^2$) **Ans**

***16-120.** Rod AB has the angular motion shown. Determine the acceleration of block C at this instant.



$\mathbf{v}_C = \mathbf{v}_B + \mathbf{v}_{C/B}$

$$\begin{bmatrix} v_C \\ \downarrow \end{bmatrix} = \begin{bmatrix} 1.5 \\ 30^\circ \end{bmatrix} + \begin{bmatrix} 0.6\omega_{CB} \\ 45^\circ \end{bmatrix}$$



$(\overset{+}{\rightarrow})$ $\quad 0 = -1.5\sin 30^\circ + 0.6\omega_{CB}\sin 45^\circ$

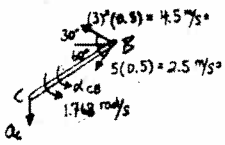
$\omega_{CB} = 1.768$ rad/s

$\mathbf{a}_C = \mathbf{a}_B + \mathbf{a}_{C/B}$

$$\begin{bmatrix} a_C \\ \downarrow \end{bmatrix} = \begin{bmatrix} 5\,(0.5) \\ 60^\circ \end{bmatrix} + \begin{bmatrix} (3)^2(0.5) \\ 30^\circ \end{bmatrix} + \begin{bmatrix} (1.768)^2(0.6) \\ 45^\circ \end{bmatrix} + \begin{bmatrix} \alpha_{CB}(0.6) \\ 45^\circ \end{bmatrix}$$

$(\overset{+}{\rightarrow})$ $\quad 0 = -2.5\cos 60^\circ - 4.5\cos 30^\circ + 1.875\cos 45^\circ + \alpha_{CB}(0.6)\cos 45^\circ$

$(+\uparrow)$ $\quad -a_C = -2.5\sin 60^\circ + 4.5\sin 30^\circ + 1.875\sin 45^\circ - \alpha_{CB}(0.6)\sin 45^\circ$



$a_C = 2.41$ m/s² $\downarrow$ **Ans**

$\alpha_{CB} = 9.01$ rad/s²

Also,

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-v_C\mathbf{j} = (-1.5\sin 30^\circ\mathbf{i} - 1.5\cos 30^\circ\mathbf{j}) + (\omega_{CB}\mathbf{k}) \times (-0.6\sin 45^\circ\mathbf{i} - 0.6\cos 45^\circ\mathbf{j})$

$(\overset{+}{\rightarrow})$ $\quad 0 = -1.5\sin 30^\circ + \omega_{CB}(0.6\cos 45^\circ)$

$\omega_{CB} = 1.768$ rad/s

$\mathbf{a}_C = \mathbf{a}_B + \boldsymbol{\alpha} \times \mathbf{r}_{C/B} - \omega^2\mathbf{r}_{C/B}$

$-a_C\mathbf{j} = (-4.5\cos 30^\circ\mathbf{i} + 4.5\sin 30^\circ\mathbf{j}) + (-2.5\cos 60^\circ\mathbf{i} - 2.5\sin 60^\circ\mathbf{j})$

$+ (\alpha_{CB}\mathbf{k}) \times (-0.6\sin 45^\circ\mathbf{i} - 0.6\cos 45^\circ\mathbf{j}) - (1.768)^2(-0.6\sin 45^\circ\mathbf{i} - 0.6\cos 45^\circ\mathbf{j})$

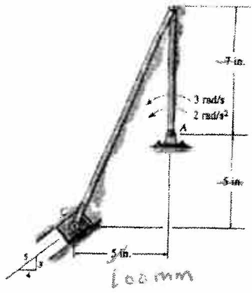
$(\overset{+}{\rightarrow})$ $\quad 0 = -4.5\cos 30^\circ - 2.5\cos 60^\circ + \alpha_{CB}(0.6\cos 45^\circ) + (1.768)^2(0.6\sin 45^\circ)$

$(+\uparrow)$ $\quad -a_C = 4.5\sin 30^\circ - 2.5\sin 60^\circ - \alpha_{CB}(0.6\sin 45^\circ) + (1.768)^2(0.6\cos 45^\circ)$

$a_C = 2.41$ m/s² $\downarrow$ **Ans**

$\alpha_{CB} = 9.01$ rad/s²

16-~~121~~ 62. At the given instant member AB has the angular motions shown. Determine the velocity and acceleration of the slider block C at this instant.



$v_B = 3(\cancel{7})^{140} = \cancel{21 \text{ in./s}} \leftarrow \quad = 420 \text{ mm/s}$

$\mathbf{v}_C = \mathbf{v}_B + \boldsymbol{\omega} \times \mathbf{r}_{C/B}$

$-v_C\left(\frac{4}{5}\right)\mathbf{i} - v_C\left(\frac{3}{5}\right)\mathbf{j} = -\cancel{21}\mathbf{i} + \omega\mathbf{k} \times (-\cancel{5}\mathbf{i} - \cancel{12}\mathbf{j})$ -420 100   240

$(\overset{+}{\rightarrow}) \qquad -0.8v_C = \cancel{-21 + 12\omega} \quad -420 + 240\omega$

$(+\uparrow) \qquad -0.6v_C = \cancel{-5\omega} \quad = -100\omega$

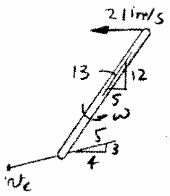
Solving :

$\omega = 1.125 \text{ rad/s}$ ✓

$v_C = \cancel{9.375 \text{ in./s}} = \cancel{9.38 \text{ in./s}}$ 187.5 mm/s $\frac{5}{4}\!\!\not{}\,3$ **Ans**

$(a_B)_n = (3)^2(\cancel{7}) = \cancel{63 \text{ in./s}^2} \downarrow$ 140 1260 mm/s^2

$(a_B)_t = (2)(\cancel{7}) = 14 \text{ in./s}^2 \leftarrow$ 140 280 mm/s^2



$\mathbf{a}_C = \mathbf{a}_B + \boldsymbol{\alpha} \times \mathbf{r}_{C/B} - \omega^2 \mathbf{r}_{C/B}$

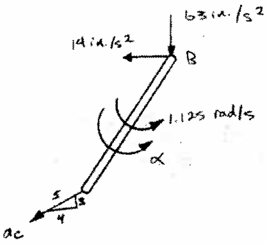
$-a_C\left(\frac{4}{5}\right)\mathbf{i} - a_C\left(\frac{3}{5}\right)\mathbf{j} = -\cancel{14}\mathbf{i} - \cancel{63}\mathbf{j} + (\alpha\mathbf{k}) \times (-\cancel{5}\mathbf{i} - \cancel{12}\mathbf{j}) - (1.125)^2(-\cancel{5}\mathbf{i} - \cancel{12}\mathbf{j})$ 280   1260 -100 240   100   240

$(\overset{+}{\rightarrow}) \qquad -0.8a_C = \cancel{-14 + 12\alpha + 6.328} \quad -280 + 240\alpha + 126.6$

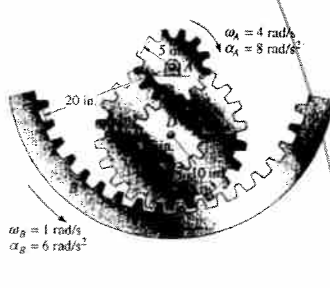
$(+\uparrow) \qquad -0.6a_C = \cancel{-63 - 5\alpha + 15.1875} \quad -1260 - 100\alpha + 303.8$

$a_C = 54.7 \text{ in./s}^2$ $\frac{5}{4}\!\!\not{}\,3$ **Ans**   ~~222 mm/s²~~ 1094 mm/s²

$\alpha = -3.00 \text{ rad/s}^2$ ~~[illegible]~~



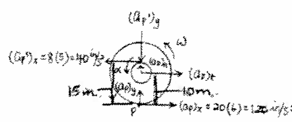
16-122. At a given instant gears A and B have the angular motions shown. Determine the angular acceleration of gear C and the acceleration of its center point D at this instant. Note that the inner hub of gear C is in mesh with gear A and its outer rim is in mesh with gear B.



$\mathbf{a}_P = \mathbf{a}_{P'} + \mathbf{a}_{P/P'}$

$(\overset{+}{\rightarrow}) \qquad 120 = -40 + \alpha(15)$

$\alpha = 10.67 \text{ rad/s}^2$ ↺   **Ans**

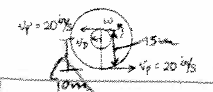


$\mathbf{a}_P = \mathbf{a}_D + \mathbf{a}_{P/D}$

$(\overset{+}{\rightarrow}) \qquad 120 = (a_D)_t + (10.67)(10)$

$(a_D)_t = 13.3 \text{ in./s}^2 \rightarrow$

$\mathbf{v}_P = \mathbf{v}_{P'} + \mathbf{v}_{P/P'}$



$(\overset{+}{\rightarrow}) \qquad 20 = -20 + \omega(15)$

$\omega = 2.667 \text{ rad/s}$

$\mathbf{v}_D = \mathbf{v}_P + \mathbf{v}_{D/P}$

$(\overset{+}{\leftarrow}) \qquad v_D = -20 + 10(2.667)$

$v_D = 6.67 \text{ in./s}$

$(a_D)_n = \frac{(6.67)^2}{10} = 4.44 \text{ in./s}^2 \uparrow$

$\theta = \tan^{-1}\left(\frac{4.44}{13.3}\right) = 18.4°$

$a_D = \sqrt{(4.44)^2 + (13.3)^2} = 14.1 \text{ in./s}^2$ **Ans**

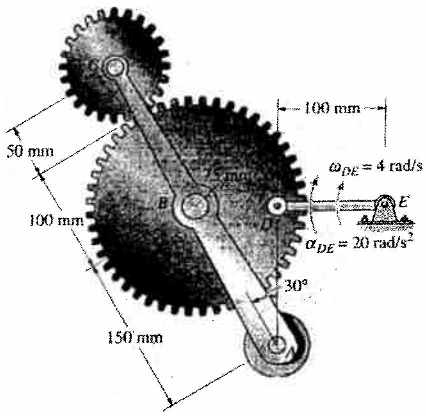
$a_C = 1593.7 + 166.7\alpha$

$1593.7 + 166.7\alpha = \cancel{4175} - \cancel{300\alpha}$

$350 + 300\alpha$

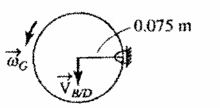
-158.25

16-123. The tied crank and gear mechanism gives rocking motion to crank AC, necessary for the operation of a printing press. If link DE has the angular motion shown, determine the respective angular velocities of gear F and crank AC at this instant, and the angular acceleration of crank AC.



Velocity analysis:

$v_D = \omega_{DE} r_{D/E} = 4(0.1) = 0.4$ m/s ↑



$\mathbf{v}_B = \mathbf{v}_D + \mathbf{v}_{B/D}$

$$\underset{\angle 30^\circ}{v_B} = \underset{\uparrow}{0.4} + \underset{\downarrow}{(\omega_G)(0.075)}$$

$(\xrightarrow{+})$ $v_B \cos 30^\circ = 0, \quad v_B = 0$

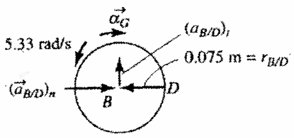
$(+\uparrow)$ $\omega_G = 5.33$ rad/s

Since $v_B = 0, \quad v_C = 0, \quad \omega_{AC} = 0$ **Ans**

$\omega_F r_F = \omega_G r_G$

$$\omega_F = 5.33\left(\frac{100}{50}\right) = 10.7 \text{ rad/s} \qquad \textbf{Ans}$$

Acceleration analysis:



$(a_D)_n = (4)^2(0.1) = 1.6$ m/s^2 →

$(a_D)_t = (20)(0.1) = 2$ m/s^2 ↑

$(\mathbf{a}_B)_n + (\mathbf{a}_B)_t = (\mathbf{a}_D)_n + (\mathbf{a}_D)_t + (\mathbf{a}_{B/D})_n + (\mathbf{a}_{B/D})_t$

$$0 + \underset{\angle 30^\circ}{(a_B)_t} = \underset{\rightarrow}{1.6} + \underset{\uparrow}{2} + \underset{\rightarrow}{(5.33)^2(0.075)} + \underset{\uparrow}{\alpha_G(0.075)}$$

$(+\uparrow)$ $(a_B)_t \sin 30^\circ = 0 + 2 + 0 + \alpha_G(0.075)$

$(\xrightarrow{+})$ $(a_B)_t \cos 30^\circ = 1.6 + 0 + (5.33)^2(0.075) + 0$

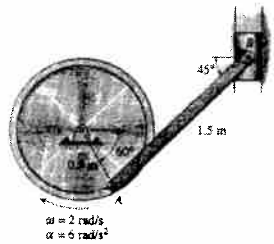
Solving,

$(a_B)_t = 4.31$ m/s^2, $\qquad \alpha_G = 2.052$ rad/s^2

Hence,

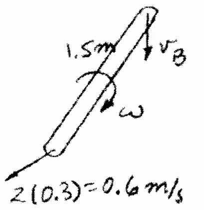
$$\alpha_{AC} = \frac{(a_B)_t}{r_{B/A}} = \frac{4.31}{0.15} = 28.7 \text{ rad/s}^2 \qquad \textbf{Ans}$$

*16-124. At a given instant the wheel is rotating with the angular velocity and angular acceleration shown. Determine the acceleration of block B at this instant.



$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{B/A}$

$$\begin{bmatrix} v_B \\ \downarrow \end{bmatrix} = \begin{bmatrix} 0.6 \\ \underset{30°}{\nearrow} \end{bmatrix} + \begin{bmatrix} \omega(1.5) \\ \underset{45°}{\searrow} \end{bmatrix}$$



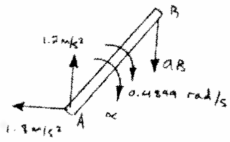
$(\overset{+}{\rightarrow})\quad 0 = -0.6\cos 30° + \omega(1.5)\cos 45°$

$\omega = 0.4899$ rad/s

$(a_A)_n = (2)^2(0.3) = 1.2$ m/s^2

$(a_A)_t = 6(0.3) = 1.8$ m/s^2

$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$



$$\begin{bmatrix} a_B \\ \downarrow \end{bmatrix} = \begin{bmatrix} 1.8 \\ \underset{30°}{\nearrow} \end{bmatrix} + \begin{bmatrix} 1.2 \\ \underset{30°}{\nwarrow} \end{bmatrix} + \begin{bmatrix} (0.4899)^2(1.5) \\ \underset{45°}{\swarrow} \end{bmatrix} + \begin{bmatrix} \alpha(1.5) \\ \underset{45°}{\nwarrow} \end{bmatrix}$$

$(\overset{+}{\rightarrow})\quad 0 = -1.8\cos 30° - 1.2\sin 30° - 0.4899(1.5)\sin 45° + \alpha(1.5)\cos 45°$

$(+\downarrow)\quad a_B = 1.8\sin 30° - 1.2\cos 30° + (0.4899)^2(1.5)\sin 45° + \alpha(1.5)\sin 45°$

$\alpha = 2.28$ rad/s^2

$a_B = 2.53$ m/s^2 **Ans**

Also :

$\mathbf{a}_B = \mathbf{a}_A + \alpha \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$-a_B\mathbf{j} = (-1.2\sin 30°\mathbf{i} + 1.2\cos 30°\mathbf{j}) + (-1.8\cos 30°\mathbf{i} - 1.8\sin 30°\mathbf{j})$

$+(-\alpha\mathbf{k}) \times (1.5\cos 45°\mathbf{i} + 1.5\sin 45°\mathbf{j})$

$-(0.4899)(1.5\cos 45°\mathbf{i} + 1.5\sin 45°\mathbf{j})$

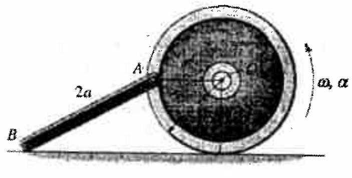
$0 = -1.2\sin 30° - 1.8\cos 30° + \alpha(1.5\sin 45°) - (0.4899)^2(1.5\cos 45°)$

$-a_B = 1.2\cos 30° - 1.8\sin 30° - \alpha(1.5\cos 45°) - (0.4899)^2(1.5\sin 45°)$

$\alpha = 2.28$ rad/s

$a_B = 2.53$ m/s^2 **Ans**

16-125. The wheel rolls without slipping such that at the instant shown it has an angular velocity ω and angular acceleration α. Determine the velocity and acceleration of point B on the rod at this instant.



Velocity:

$$(\overset{+}{\leftarrow})\quad v_B = \left(\frac{1}{\sqrt{2}}\right)(\sqrt{2}a\omega) + \frac{\omega}{\sqrt{3}}(2a)\left(\frac{1}{2}\right)$$

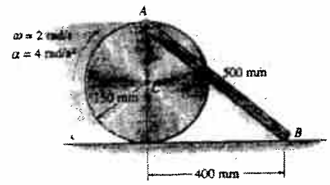
$v_B = 1.58\,\omega a$ **Ans**

Acceleration:

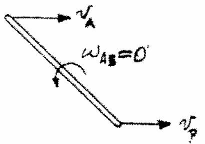
$$(\overset{+}{\leftarrow})\quad a_B = -\omega^2 a + \alpha a - \frac{\omega^2}{3}(2a)\cos 30° + \left(\frac{\alpha}{\sqrt{3}} - \frac{\omega^2}{3\sqrt{3}}\right)(2a)\sin 30°$$

$a_B = 1.58\,\alpha a - 1.77\,\omega^2 a$ **Ans**

16-126. The disk rolls without slipping such that it has an angular acceleration of $\alpha = 4$ rad/s^2 and angular velocity of $\omega = 2$ rad/s at the instant shown. Determine the accelerations of points A and B on the link and the link's angular acceleration at this instant. Assume point A lies on the periphery of the disk, 150 mm from C.



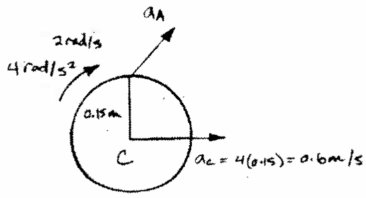
The IC is at ∞, so $\omega = 0$.



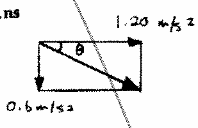
$\mathbf{a}_A = \mathbf{a}_C + \boldsymbol{\alpha} \times \mathbf{r}_{A/C} - \omega^2 \mathbf{r}_{A/C}$

$\mathbf{a}_A = 0.6\mathbf{i} + (-4\mathbf{k}) \times (0.15\mathbf{j}) - (2)^2(0.15\mathbf{j})$

$\mathbf{a}_A = \{1.20\mathbf{i} - 0.6\mathbf{j}\}$ m/s^2



$a_A = \sqrt{(1.20)^2 + (-0.6)^2} = 1.34$ m/s^2 **Ans**



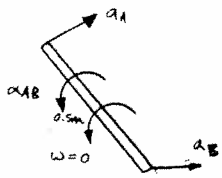
$\theta = \tan^{-1}\left(\frac{0.6}{1.20}\right) = 26.6°$ **Ans**

$\mathbf{a}_B = \mathbf{a}_A + \boldsymbol{\alpha} \times \mathbf{r}_{B/A} - \omega^2 \mathbf{r}_{B/A}$

$a_B \mathbf{i} = 1.20\mathbf{i} - 0.6\mathbf{j} + \alpha_{AB}\mathbf{k} \times (0.4\mathbf{i} - 0.3\mathbf{j}) - \mathbf{0}$

$(\xrightarrow{+})$ $\quad a_B = 1.20 + 0.3\alpha_{AB}$

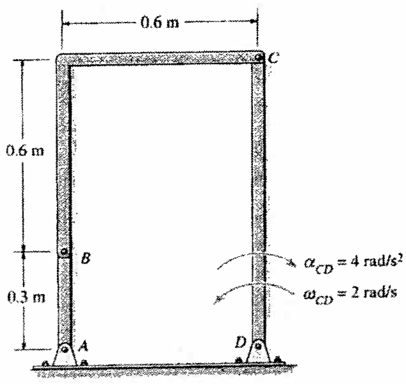
$(+\uparrow)$ $\quad 0 = -0.6 + 0.4\alpha_{AB}$



$\alpha_{AB} = 1.5$ rad/s^2 **Ans**

$a_B = 1.65$ m/s^2 $\rightarrow$ **Ans**

16-127. Determine the angular acceleration of link AB if link CD has the angular velocity and angular deceleration shown.



IC is at ∞, thus

$\omega_{BC} = 0$

$v_B = v_C = (0.9)(2) = 1.8$ m/s

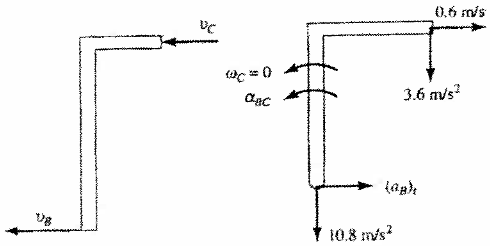
$(a_C)_n = (2)^2(0.9) = 3.6$ m/s^2 $\downarrow$

$(a_C)_t = 4(0.9) = 3.6$ m/s^2 $\rightarrow$

$(a_B)_n = \frac{(1.8)^2}{0.3} = 10.8$ m/s^2 $\downarrow$

$\mathbf{a}_B = \mathbf{a}_C + \alpha_{BC} \times \mathbf{r}_{B/C} - \omega_{BC}^2 \mathbf{r}_{B/C}$

$(a_B)_t \mathbf{i} - 10.8\mathbf{j} = 3.6\mathbf{i} - 3.6\mathbf{j} + (\alpha_{BC}\mathbf{k}) \times (-0.6\mathbf{i} - 0.6\mathbf{j}) - \mathbf{0}$



$(\xrightarrow{+})$ $\quad (a_B)_t = 3.6 + 0.6\alpha_{BC}$

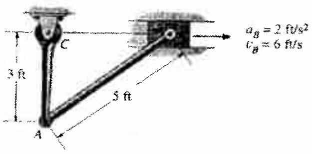
$(+\uparrow)$ $\quad -10.8 = -3.6 - 0.6\alpha_{BC}$

$\alpha_{BC} = 12$ rad/s^2

$(a_B)_t = 10.8$ m/s^2

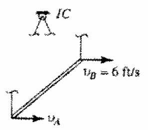
$\alpha_{AB} = \frac{10.8}{0.3} = 36$ rad/s^2 **Ans**

***16-128.** The slider block B is moving to the right with an acceleration of 2 ft/s^2. At the instant shown, its velocity is 6 ft/s. Determine the angular acceleration of link AB and the acceleration of point A at this instant.



$$\omega_{AB} = \frac{v_B}{r_{B/IC}} = \frac{6}{\infty} = 0 \quad v_A = v_B = 6 \text{ ft/s}$$

$$\omega_{AC} = \frac{v_A}{r_{AC}} = \frac{6}{3} = 2 \text{ rad/s}$$



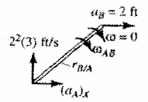
$\mathbf{a}_B = \{2\mathbf{i}\}$ ft/s $\quad \mathbf{a}_A = (a_A)_x\mathbf{i} + (2)^2(3)\mathbf{j} = (a_A)_x\mathbf{i} + 12\mathbf{j}$

$\boldsymbol{\alpha}_{AB} = -\alpha_{AB}\mathbf{k} \quad \mathbf{r}_{B/A} = \{4\mathbf{i} + 3\mathbf{j}\}$ ft

$\mathbf{a}_B = \mathbf{a}_A + \boldsymbol{\alpha}_{AB} \times \mathbf{r}_{B/A} - \omega_{AB}^2\mathbf{r}_{B/A}$

$2\mathbf{i} = [(a_A)_x\mathbf{i} + 12\mathbf{j}] + (-\alpha_{AB}\mathbf{k}) \times (4\mathbf{i} + 3\mathbf{j}) - \mathbf{0}$

$2\mathbf{i} = [(a_A)_x + 3\alpha_{AB}]\mathbf{i} + (12 - 4\alpha_{AB})\mathbf{j}$



$0 = 12 - 4\alpha_{AB} \qquad \alpha_{AB} = 3 \text{ rad/s}^2$ **Ans**

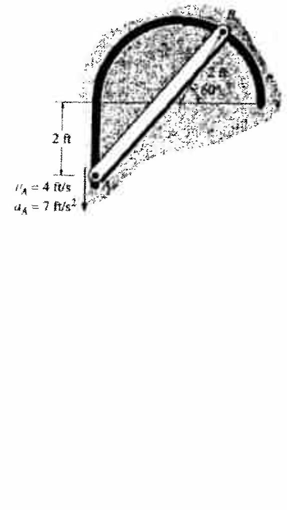
$2 = (a_A)_x + 3(3) \qquad (a_A)_x = -7 \text{ ft/s}^2$

$\mathbf{a}_A = \{-7\mathbf{i} + 12\mathbf{j}\}$ ft/s^2 **Ans**

$a_A = \sqrt{(-7)^2 + 12^2} = 13.9$ ft/s^2 **Ans**

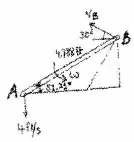
$\theta = \tan^{-1}\frac{12}{7} = 59.7°$ **Ans**

16-129. The ends of the bar AB are confined to move along the paths shown. At a given instant, A has a velocity of $v_A = 4$ ft/s and an acceleration of $a_A = 7$ ft/s^2. Determine the angular velocity and angular acceleration of AB at this instant.



$\mathbf{v}_B = \mathbf{v}_A + \mathbf{v}_{B/A}$

$v_B \;(30°) = 4\downarrow + \omega(4.788)\;(51.21°)$



$(\xrightarrow{+})\quad -v_B\cos 30° = 0 - \omega(4.788)\sin 51.21°$

$(+\uparrow)\quad v_B\sin 30° = -4 + \omega(4.788)\cos 51.21°$

$v_B = 20.39$ ft/s $\quad 30°$

$\omega = 4.73$ rad/s **Ans**

$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$

$a_t\;(30°) + 207.9\;(60°) = 7\downarrow + 107.2\;(51.21°) + 4.788(\alpha)\;(51.21°)$

$(\xleftarrow{+})\quad a_t\cos 30° + 207.9\cos 60° = 0 + 107.2\cos 51.21° + 4.788\alpha(\sin 51.21°)$

$(+\uparrow)\quad a_t\sin 30° - 207.9\sin 60° = -7 - 107.2\sin 51.21° + 4.788\alpha(\cos 51.21°)$

$a_t(0.866) - 3.732\alpha = -36.78$

$a_t(0.5) - 3\alpha = 89.49$

$a_t = -607$ ft/s^2

$\alpha = -131$ rad/s^2 $= 131$ rad/s^2 **Ans**

Also:

$\mathbf{v}_B = \mathbf{v}_A = \boldsymbol{\omega} \times \mathbf{r}_{B/A}$

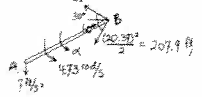
$-v_B\cos 30°\mathbf{i} + v_B\sin 30°\mathbf{j} = -4\mathbf{j} + (\omega\mathbf{k}) \times (3\mathbf{i} + 3.732\mathbf{j})$

$-v_B\cos 30° = -\omega(3.732)$

$v_B\sin 30° = -4 + \omega(3)$

$\omega = 4.73$ rad/s **Ans**

$v_B = 20.39$ ft/s



$\mathbf{a}_B = \mathbf{a}_A - \omega^2\mathbf{r}_{B/A} + \boldsymbol{\alpha} \times \mathbf{r}_{B/A}$

$(-a_t\cos 30°\mathbf{i} + a_t\sin 30°\mathbf{j}) + (-207.9\cos 60°\mathbf{i} - 207.9\sin 60°\mathbf{j}) = -7\mathbf{j} - (4.732)^2(3\mathbf{i} + 3.732\mathbf{j}) + (\alpha\mathbf{k}) \times (3\mathbf{i} + 3.732\mathbf{j})$

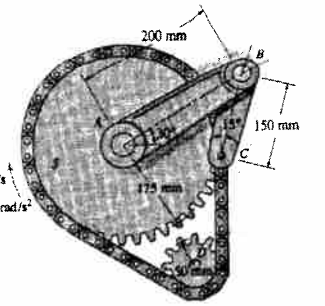
$-a_t\cos 30° - 207.9\cos 60° = -(4.732)^2(3) - \alpha(3.732)$

$a_t\sin 30° - 207.9\sin 60° = -7 - (4.732)^2(3.732) + \alpha(3)$

$a_t = -607$ ft/s^2

$\alpha = -131$ rad/s^2 $= 131$ rad/s^2 **Ans**

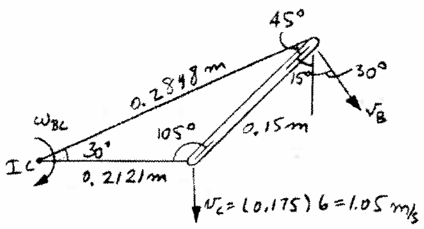
16-130. The mechanism produces intermittent motion of link AB. If the sprocket S is turning with an angular acceleration $\alpha_S = 2\ \text{rad/s}^2$ and has an angular velocity $\omega_S = 6$ rad/s at the instant shown, determine the angular velocity and angular acceleration of link AB at this instant. The sprocket S is mounted on a shaft which is *separate* from a collinear shaft attached to AB at A. The pin at C is attached to one of the chain links such that it moves vertically downward.



$$\omega_{BC} = \frac{1.05}{0.2121} = 4.950 \text{ rad/s}$$

$$v_B = (4.95)(0.2898) = 1.434 \text{ m/s}$$

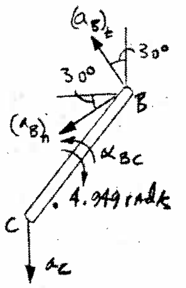
$$\omega_{AB} = \frac{1.435}{0.2} = 7.1722 \text{ rad/s} = 7.17 \text{ rad/s} \circlearrowright \qquad \textbf{Ans}$$



$$a_C = \alpha_S r_S = 2(0.175) = 0.350 \text{ m/s}^2$$

$$(\mathbf{a}_B)_n + (\mathbf{a}_B)_t = \mathbf{a}_C + (\mathbf{a}_{B/C})_n + (\mathbf{a}_{B/C})_t$$

$$\begin{bmatrix} (7.172)^2(0.2) \\ \underset{30°}{\swarrow} \end{bmatrix} + \begin{bmatrix} (a_B)_t \\ \underset{30°}{\nwarrow} \end{bmatrix} = \begin{bmatrix} 0.350 \\ \downarrow \end{bmatrix} + \begin{bmatrix} (4.949)^2(0.15) \\ \underset{15°}{\swarrow} \end{bmatrix} + \begin{bmatrix} \alpha_{BC}(0.15) \\ \underset{15°}{\searrow} \end{bmatrix}$$



$(\overset{+}{\rightarrow})$ $\quad -(10.29)\cos 30° - (a_B)_t \sin 30° = 0 - (4.949)^2(0.15)\sin 15° - \alpha_{BC}(0.15)\cos 15°$

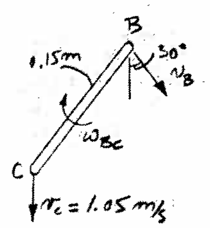
$(+\uparrow)$ $\quad -(10.29)\sin 30° + (a_B)_t \cos 30° = -0.350 - (4.949)^2(0.15)\cos 15° + \alpha_{BC}(0.15)\sin 15°$

$\alpha_{BC} = 70.8 \text{ rad/s}^2, \qquad (a_B)_t = 4.61 \text{ m/s}^2$

Hence,

$$\alpha_{AB} = \frac{(a_B)_t}{r_{B/A}} = \frac{4.61}{0.2} = 23.1 \text{ rad/s}^2 \circlearrowright \qquad \textbf{Ans}$$

Also,



$$v_C = \omega_S r_S = 6(0.175) = 1.05 \text{ m/s} \downarrow$$

$$\mathbf{v}_B = \mathbf{v}_C + \omega_{BC} \times \mathbf{r}_{B/C}$$

$$v_B \sin 30°\mathbf{i} - v_B \cos 30°\mathbf{j} = -1.05\mathbf{j} + (-\omega_{BC}\mathbf{k}) \times (0.15 \sin 15°\mathbf{i} + 0.15 \cos 15°\mathbf{j})$$

$(\overset{+}{\rightarrow})$ $\quad v_B \sin 30° = 0 + \omega_{BC}(0.15)\cos 15°$

$(+\uparrow)$ $\quad -v_B \cos 30° = -1.05 - \omega_{BC}(0.15)\sin 15°$

$v_B = 1.434 \text{ m/s}, \qquad \omega_{BC} = 4.950 \text{ rad/s}$

$$\omega_{AB} = \frac{v_B}{r_{B/A}} = \frac{1.434}{0.2} = 7.172 = 7.17 \text{ rad/s} \circlearrowright \qquad \textbf{Ans}$$

$$\mathbf{a}_B = \mathbf{a}_C + \alpha_{BC} \times \mathbf{r}_{B/C} - \omega^2 \mathbf{r}_{B/C}$$

$$(\alpha_{AB}\mathbf{k}) \times (0.2\cos 30°\mathbf{i} + 0.2\sin 30°\mathbf{j}) - (7.172)^2(0.2\cos 30°\mathbf{i} + 0.2\sin 30°\mathbf{j})$$

$$= -(2)(0.175)\mathbf{j} + (\alpha_{BC}\mathbf{k}) \times (0.15\sin 15°\mathbf{i} + 0.15\cos 15°\mathbf{j}) - (4.950)^2(0.15\sin 15°\mathbf{i} + 0.15\cos 15°\mathbf{j})$$

$(\overset{+}{\rightarrow})$ $\quad -\alpha_{AB}(0.1) - 8.9108 = -0.1449\alpha_{BC} - 0.9512$

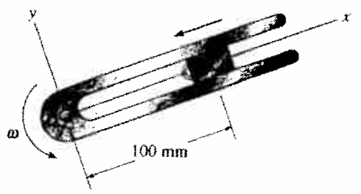
$(+\uparrow)$ $\quad \alpha_{AB}(0.1732) - 5.143 = -0.350 + 0.0388\alpha_{BC} - 3.550$

$\alpha_{AB} = 23.1 \text{ rad/s}^2 \circlearrowright \qquad \textbf{Ans}$

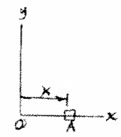
$\alpha_{BC} = 70.8 \text{ rad/s}^2$

65

16-~~131~~. Block A, which is attached to a cord, moves along the slot of a horizontal forked rod. At the instant shown, the cord is pulled down through the hole at O with an acceleration of $4\ \text{m/s}^2$ and its velocity is $2\ \text{m/s}$. Determine the acceleration of the block at this instant. The rod rotates about O with a constant angular velocity $\omega = 4$ rad/s.



Motion of moving reference.



$\mathbf{v}_O = \mathbf{0}$

$\mathbf{a}_O = \mathbf{0}$

$\Omega = 4\mathbf{k}$

$\dot{\Omega} = \mathbf{0}$

Motion of A with respect to moving reference.

$\mathbf{r}_{A/O} = 0.1\mathbf{i}$

$\mathbf{v}_{A/O} = -2\mathbf{i}$

$\mathbf{a}_{A/O} = -4\mathbf{i}$

Thus,

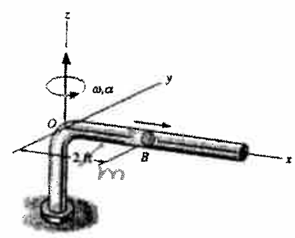
$$\mathbf{a}_A = \mathbf{a}_O + \dot{\Omega}\times\mathbf{r}_{A/O} + \Omega\times(\Omega\times\mathbf{r}_{A/O}) + 2\Omega\times(\mathbf{v}_{A/O})_{xyz} + (\mathbf{a}_{A/O})_{xyz}$$

$$= \mathbf{0} + \mathbf{0} + (4\mathbf{k})\times(4\mathbf{k}\times 0.1\mathbf{i}) + 2(4\mathbf{k}\times(-2\mathbf{i})) - 4\mathbf{i}$$

$$\mathbf{a}_A = \{-5.60\mathbf{i} - 16\mathbf{j}\}\ \text{m/s}^2 \qquad \textbf{Ans}$$

66

***16-~~132~~.** The ball B of negligible size rolls through the tube such that at the instant shown it has a velocity of ~~5 ft/s~~ 2 m/s and an acceleration of ~~3 ft/s²~~ 1 m/s², measured relative to the tube. If the tube has an angular velocity of $\omega = 3$ rad/s and an angular acceleration of $\alpha = 5\ \text{rad/s}^2$ at this same instant, determine the velocity and acceleration of the ball.



Kinematic Equations :

$$\mathbf{v}_B = \mathbf{v}_O + \Omega\times\mathbf{r}_{B/O} + (\mathbf{v}_{B/O})_{xyz} \qquad (1)$$

$$\mathbf{a}_B = \mathbf{a}_O + \dot{\Omega}\times\mathbf{r}_{B/O} + \Omega\times(\Omega\times\mathbf{r}_{B/O}) + 2\Omega\times(\mathbf{v}_{B/O})_{xyz} + (\mathbf{a}_{B/O})_{xyz} \qquad (2)$$

$\mathbf{v}_O = \mathbf{0}$

$\mathbf{a}_O = \mathbf{0}$

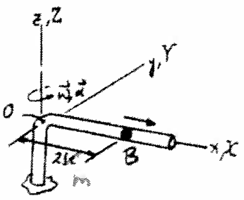
$\Omega = \{3\mathbf{k}\}$ rad/s

$\dot{\Omega} = \{5\mathbf{k}\}\ \text{rad/s}^2$

$\mathbf{r}_{B/O} = \{2\mathbf{i}\}$ ~~ft~~ m

$(\mathbf{v}_{B/O})_{xyz} = \{\overset{2}{\cancel{5}}\mathbf{i}\}$ ~~ft/s~~ m

$(\mathbf{a}_{B/O})_{xyz} = \{\overset{1}{\cancel{3}}\mathbf{i}\}$ ~~ft/s²~~ m



Substitute the data into Eqs. (1) and (2) yields :

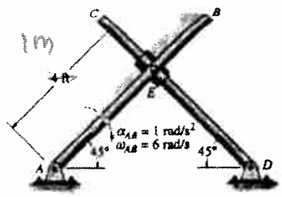
$$\mathbf{v}_B = \mathbf{0} + (3\mathbf{k})\times(2\mathbf{i}) + (\overset{2}{\cancel{5}}\mathbf{i}) = \{\overset{2}{\cancel{5}}\mathbf{i} + 6\mathbf{j}\}\ \cancel{\text{ft/s}}\ \text{m/s} \qquad \textbf{Ans}$$

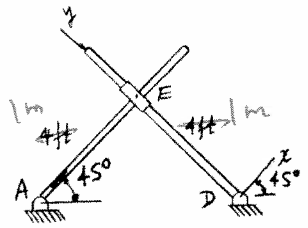
$$\mathbf{a}_B = \mathbf{0} + (5\mathbf{k})\times(2\mathbf{i}) + (3\mathbf{k})\times\left[(3\mathbf{k})\times(2\mathbf{i})\right] + 2(3\mathbf{k})\times(\overset{2}{\cancel{5}}\mathbf{i}) + (\overset{1}{\cancel{3}}\mathbf{i})$$

$$= \{-15\mathbf{i} + 40\mathbf{j}\}\ \text{ft/s}^2 \qquad \textbf{Ans}$$

$(-17i + 22j)\ \text{m/s}^2$

16-1$\overset{67}{\cancel{33}}$. The collar E is attached to, and pivots about, rod AB while it slides on rod CD. If rod AB has an angular velocity of 6 rad/s and an angular acceleration of 1 rad/s^2, both acting clockwise, determine the angular velocity and the angular acceleration of rod CD at the instant shown.





Fix axes to ED.

$\Omega = \omega_{CD}\mathbf{k}$

$\dot{\Omega} = \alpha_{CD}\mathbf{k}$

$\mathbf{r}_{E/D} = \cancel{4}\mathbf{j}$ $1\mathbf{j}$

$\mathbf{v}_{E/D} = v_{E/D}\mathbf{j}$

$\mathbf{a}_{E/D} = a_{E/D}\mathbf{j}$

$\mathbf{v}_E = -6(\overset{1}{\cancel{4}})\mathbf{j} = \cancel{-24}\mathbf{j}$ $-6\mathbf{j}$

$\mathbf{a}_E = -(6)^2(\overset{1}{\cancel{4}})\mathbf{i} - 1(\overset{1}{\cancel{4}})\mathbf{j} = -\overset{36}{\cancel{144}}\mathbf{i} - \overset{1}{\cancel{4}}\mathbf{j}$

$\mathbf{v}_E = \mathbf{v}_D + \Omega \times \mathbf{r}_{E/D} + (\mathbf{v}_{E/D})_{xyz}$

$-\overset{6}{\cancel{24}}\mathbf{j} = \mathbf{0} + \omega_{CD}\mathbf{k} \times \overset{1}{\cancel{4}}\mathbf{j} + v_{E/D}\mathbf{j}$

$-\overset{6}{\cancel{24}}\mathbf{j} = -\cancel{4}\omega_{CD}\mathbf{i} + v_{E/D}\mathbf{j}$

Thus,

$\omega_{CD} = 0$ **Ans**

$v_{E/D} = -\overset{6}{\cancel{24}}$ ~~ft/s~~ -6 m/s

$\mathbf{a}_E = \mathbf{a}_D + \dot{\Omega} \times \mathbf{r}_{E/D} + \Omega \times (\Omega \times \mathbf{r}_{E/D}) + 2\Omega \times (\mathbf{v}_{E/D})_{xyz} + (\mathbf{a}_{E/D})_{xyz}$

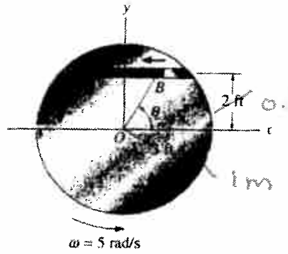
$-\overset{36}{\cancel{144}}\mathbf{i} - \overset{1}{\cancel{4}}\mathbf{j} = \mathbf{0} + \alpha_{CD}\mathbf{k} \times \overset{1}{\cancel{4}}\mathbf{j} + \mathbf{0} + \mathbf{0} + a_{E/D}\mathbf{j}$

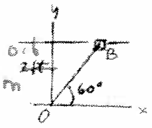
$-\overset{36}{\cancel{144}}\mathbf{i} - \overset{1}{\cancel{4}}\mathbf{j} = -\alpha_{CD}(\overset{1}{\cancel{4}})\mathbf{i} + a_{E/D}\mathbf{j}$

$\alpha_{CD} = \dfrac{\overset{36}{\cancel{144}}}{\underset{1}{\cancel{4}}} = 36 \text{ rad/s}^2$ **Ans**

$a_{E/D} = -4$ ~~ft/s^2~~ -1 m/s^2

16-~~134~~ 68. Block B moves along the slot in the platform with a constant speed of ~~2 ft/s~~ 0.6 m/s, measured relative to the platform in the direction shown. If the platform is rotating at a constant rate of $\omega = 5$ rad/s, determine the velocity and acceleration of the block at the instant $\theta = 60°$.





$$\mathbf{r}_{B/O} = \frac{\cancel{2}\ 0.6}{\tan 60°}\mathbf{i} + \cancel{2}\,0.6\,\mathbf{j} = \cancel{\{1.55\mathbf{i} + 2\mathbf{j}\}\text{ ft}}$$

$(0.346\,i + 0.6j)$ m

$$\mathbf{v}_B = \mathbf{v}_O + \Omega \times \mathbf{r}_{B/O} + (\mathbf{v}_{B/O})_{xyz}$$

$0.346i + 0.6j - 0.6i$

$$\mathbf{v}_B = 0 + 5\mathbf{k} \times (\cancel{1.155}\mathbf{i} + 2\mathbf{j}) - \cancel{2}\mathbf{i}$$

$(-3.6i + 1.73j)$ m/s

$$\mathbf{v}_B = \cancel{\{-12.0\mathbf{i} + 5.77\mathbf{j}\}\text{ ft/s}} \qquad \textbf{Ans}$$

$$\mathbf{a}_B = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{B/O} + \Omega \times (\Omega \times \mathbf{r}_{B/O}) + 2\Omega \times (\mathbf{v}_{B/O})_{xyz} + (\mathbf{a}_{B/O})_{xyz}$$

$0.346i + 0.6j$

$$\mathbf{a}_B = 0 + 0 + 5\mathbf{k} \times [(5\mathbf{k}) \times (\cancel{1.155\mathbf{i} + 2\mathbf{j}})] + 2(5\mathbf{k}) \times (-\cancel{2}\mathbf{i}) + 0$$

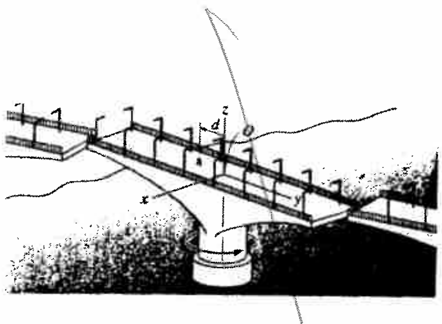
$-0.6i$

$$\mathbf{a}_B = 0 + 0 - \cancel{28.87}\ 8.65\,\mathbf{i} - \cancel{50}\ 15\,\mathbf{j} - \cancel{20}\ 6\,\mathbf{j}$$

$$\mathbf{a}_B = \cancel{\{-28.9\mathbf{i} - 70.0\mathbf{j}\}\text{ ft/s}^2} \qquad \textbf{Ans}$$

$= \{-8.65\,i - 21\,j\}$ m/s^2

16-135. While the swing bridge is closing with a constant rotation of 0.5 rad/s, a man runs along the roadway at a constant speed of 5 ft/s relative to the roadway. Determine his velocity and acceleration at the instant $d = 15$ ft.



$$\Omega = \{0.5\mathbf{k}\}\text{ rad/s}$$

$$\dot{\Omega} = \mathbf{0}$$

$$\mathbf{r}_{m/O} = \{-15\,\mathbf{j}\}\text{ ft}$$

$$(\mathbf{v}_{m/O})_{xyz} = \{-5\mathbf{j}\}\text{ ft/s}$$

$$(\mathbf{a}_{m/O})_{xyz} = \mathbf{0}$$

$$\mathbf{v}_m = \mathbf{v}_O + \Omega \times \mathbf{r}_{m/O} + (\mathbf{v}_{m/O})_{xyz}$$

$$\mathbf{v}_m = 0 + (0.5\mathbf{k}) \times (-15\mathbf{j}) - 5\mathbf{j}$$

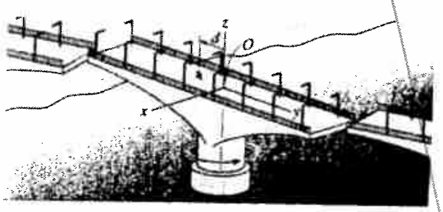
$$\mathbf{v}_m = \{7.5\mathbf{i} - 5\mathbf{j}\}\text{ ft/s} \qquad \textbf{Ans}$$

$$\mathbf{a}_m = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{m/O} + \Omega \times (\Omega \times \mathbf{r}_{m/O}) + 2\Omega \times (\mathbf{v}_{m/O})_{xyz} + (\mathbf{a}_{m/O})_{xyz}$$

$$\mathbf{a}_m = \mathbf{0} + \mathbf{0} + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (-15\mathbf{j})] + 2(0.5\mathbf{k}) \times (-5\mathbf{j}) + \mathbf{0}$$

$$\mathbf{a}_m = \{5\mathbf{i} + 3.75\mathbf{j}\}\text{ ft/s}^2 \qquad \textbf{Ans}$$

***16-136.** While the swing bridge is closing with a constant rotation of 0.5 rad/s, a man runs along the roadway such that when $d = 10$ ft he is running outward from the center at 5 ft/s with an acceleration of 2 ft/s², both measured relative to the roadway. Determine his velocity and acceleration at this instant.



$$\Omega = \{0.5\mathbf{k}\}\text{ rad/s}$$

$$\dot{\Omega} = \mathbf{0}$$

$$\mathbf{r}_{m/O} = \{-10\,\mathbf{j}\}\text{ ft}$$

$$(\mathbf{v}_{m/O})_{xyz} = \{-5\mathbf{j}\}\text{ ft/s}$$

$$(\mathbf{a}_{m/O})_{xyz} = \{-2\mathbf{j}\}\text{ ft/s}^2$$

$$\mathbf{v}_m = \mathbf{v}_O + \Omega \times \mathbf{r}_{m/O} + (\mathbf{v}_{m/O})_{xyz}$$

$$\mathbf{v}_m = 0 + (0.5\mathbf{k}) \times (-10\mathbf{j}) - 5\mathbf{j}$$

$$\mathbf{v}_m = \{5\mathbf{i} - 5\mathbf{j}\}\text{ ft/s} \qquad \textbf{Ans}$$

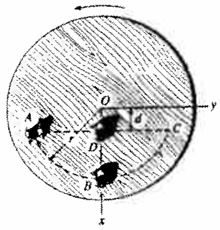
$$\mathbf{a}_m = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{m/O} + \Omega \times (\Omega \times \mathbf{r}_{m/O}) + 2\Omega \times (\mathbf{v}_{m/O})_{xyz} + (\mathbf{a}_{m/O})_{xyz}$$

$$\mathbf{a}_m = \mathbf{0} + \mathbf{0} + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (-10\mathbf{j})] + 2(0.5\mathbf{k}) \times (-5\mathbf{j}) - 2\mathbf{j}$$

$$\mathbf{a}_m = \{5\mathbf{i} + 0.5\mathbf{j}\}\text{ ft/s}^2 \qquad \textbf{Ans}$$

169

16-137. A girl stands at A on a platform which is rotating with a constant angular velocity $\omega = 0.5$ rad/s. If she walks at a constant speed of $v = 0.75$ m/s measured relative to the platform, determine her acceleration (a) when she reaches point D in going along the path ADC, $d = 1$ m; and (b) when she reaches point B if she follows the path ABC, $r = 3$ m.



(a)

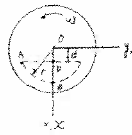
$$\mathbf{a}_D = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{D/O} + \Omega \times (\Omega \times \mathbf{r}_{D/O}) + 2\Omega \times (\mathbf{v}_{D/O})_{xyz} + (\mathbf{a}_{D/O})_{xyz} \qquad [1]$$

Motion of moving reference | *Motion of D with respect to moving reference*

$\mathbf{a}_O = \mathbf{0}$ | $\mathbf{r}_{D/O} = \{1\mathbf{i}\}$ m

$\Omega = \{0.5\mathbf{k}\}$ rad/s | $(\mathbf{v}_{D/O})_{xyz} = \{0.75\mathbf{j}\}$ m/s

$\dot{\Omega} = \mathbf{0}$ | $(\mathbf{a}_{D/O})_{xyz} = \mathbf{0}$



Substitute the data into Eq.[1] :

$$\mathbf{a}_B = \mathbf{0} + (\mathbf{0}) \times (1\mathbf{i}) + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (1\mathbf{i})] + 2(0.5\mathbf{k}) \times (0.75\mathbf{j}) + \mathbf{0}$$

$$= \{-1\mathbf{i}\}\ \text{m/s}^2 \qquad \textbf{Ans}$$

(b)

$$\mathbf{a}_B = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{B/O} + \Omega \times (\Omega \times \mathbf{r}_{B/O}) + 2\Omega \times (\mathbf{v}_{B/O})_{xyz} + (\mathbf{a}_{B/O})_{xyz} \qquad [2]$$

Motion of moving reference | *Motion of B with respect to moving reference*

$\mathbf{a}_O = \mathbf{0}$ | $\mathbf{r}_{B/O} = \{3\mathbf{i}\}$ m

$\Omega = \{0.5\mathbf{k}\}$ rad/s | $(\mathbf{v}_{B/O})_{xyz} = \{0.75\mathbf{j}\}$ m/s

$\dot{\Omega} = \mathbf{0}$ | $(\mathbf{a}_{B/O})_{xyz} = -(a_{B/O})_n\mathbf{i} + (a_{B/O})_t\mathbf{j}$

$$= -\left(\frac{0.75^2}{3}\right)\mathbf{i}$$

$$= \{-0.1875\mathbf{i}\}\ \text{m/s}$$

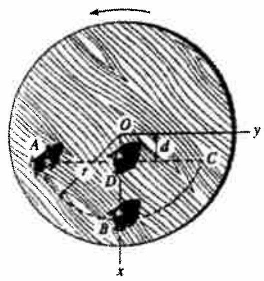
Substitute the data into Eq.[2] :

$$\mathbf{a}_B = \mathbf{0} + (\mathbf{0}) \times (3\mathbf{i}) + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (3\mathbf{i})] + 2(0.5\mathbf{k}) \times (0.75\mathbf{j}) + (-0.1875\mathbf{i})$$

$$= \{-1.69\mathbf{i}\}\ \text{m/s}^2 \qquad \textbf{Ans}$$

170

16-138. A girl stands at A on a platform which is rotating with an angular acceleration $\alpha = 0.2$ rad/s^2 and at the instant shown has an angular velocity $\omega = 0.5$ rad/s. If she walks at a constant speed $v = 0.75$ m/s measured relative to the platform, determine her acceleration (a) when she reaches point D in going along the path ADC, $d = 1$ m; and (b) when she reaches point B if she follows the path ABC, $r = 3$ m.



(a)

$$\mathbf{a}_D = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{D/O} + \Omega \times (\Omega \times \mathbf{r}_{D/O}) + 2\Omega \times (\mathbf{v}_{D/O})_{xyz} + (\mathbf{a}_{D/O})_{xyz} \qquad [1]$$

Motion of moving reference | *Motion of D with respect to moving reference*

$\mathbf{a}_O = \mathbf{0}$ | $\mathbf{r}_{D/O} = \{1\mathbf{i}\}$ m

$\Omega = \{0.5\mathbf{k}\}$ rad/s | $(\mathbf{v}_{D/O})_{xyz} = \{0.75\mathbf{j}\}$ m/s

$\dot{\Omega} = \{0.2\mathbf{k}\}$ rad/s^2 | $(\mathbf{a}_{D/O})_{xyz} = \mathbf{0}$

Substitute the data into Eq.[1] :

$$\mathbf{a}_B = \mathbf{0} + (0.2\mathbf{k}) \times (1\mathbf{i}) + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (1\mathbf{i})] + 2(0.5\mathbf{k}) \times (0.75\mathbf{j}) + \mathbf{0}$$

$$= \{-1\mathbf{i} + 0.2\mathbf{j}\}\ \text{m/s}^2 \qquad \textbf{Ans}$$

(b)

$$\mathbf{a}_B = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{B/O} + \Omega \times (\Omega \times \mathbf{r}_{B/O}) + 2\Omega \times (\mathbf{v}_{B/O})_{xyz} + (\mathbf{a}_{B/O})_{xyz} \qquad [2]$$

Motion of moving reference | *Motion of B with respect to moving reference*

$\mathbf{a}_O = \mathbf{0}$ | $\mathbf{r}_{B/O} = \{3\mathbf{i}\}$ m

$\Omega = \{0.5\mathbf{k}\}$ rad/s | $(\mathbf{v}_{B/O})_{xyz} = \{0.75\mathbf{j}\}$ m/s

$\dot{\Omega} = \{0.2\mathbf{k}\}$ rad/s^2 | $(\mathbf{a}_{B/O})_{xyz} = -(a_{B/O})_n\mathbf{i} + (a_{B/O})_t\mathbf{j}$

$$= -\left(\frac{0.75^2}{3}\right)\mathbf{i}$$

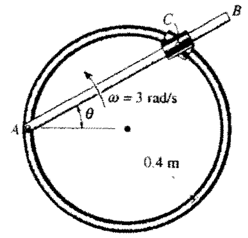
$$= \{-0.1875\mathbf{i}\}\ \text{m/s}$$

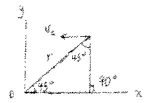
Substitute the data into Eq.[2] :

$$\mathbf{a}_B = \mathbf{0} + (0.2\mathbf{k}) \times (3\mathbf{i}) + (0.5\mathbf{k}) \times [(0.5\mathbf{k}) \times (3\mathbf{i})] + 2(0.5\mathbf{k}) \times (0.75\mathbf{j}) + (-0.1875\mathbf{i})$$

$$= \{-1.69\mathbf{i} + 0.6\mathbf{j}\}\ \text{m/s}^2 \qquad \textbf{Ans}$$

16-139. Rod AB rotates counterclockwise with a constant angular velocity $\omega = 3$ rad/s. Determine the velocity and acceleration of point C located on the double collar when $\theta = 45°$. The collar consists of two pin-connected slider blocks which are constrained to move along the circular path and the rod AB.





$$\mathbf{r}_{C/A} = \{0.400\mathbf{i} + 0.400\mathbf{j}\}$$

$$\mathbf{v}_C = -v_C\mathbf{i}$$

$$\mathbf{v}_C = \mathbf{v}_A + \Omega \times \mathbf{r}_{C/A} + (\mathbf{v}_{C/A})_{xyz}$$

$$-v_C\mathbf{i} = 0 + (3\mathbf{k}) \times (0.400\mathbf{i} + 0.400\mathbf{j}) + (v_{C/A}\cos 45°\mathbf{i} + v_{C/A}\sin 45°\mathbf{j})$$

$$-v_C\mathbf{i} = 0 - 1.20\mathbf{i} + 1.20\mathbf{j} + 0.707v_{C/A}\mathbf{i} + 0.707v_{C/A}\mathbf{j}$$

$$-v_C = -1.20 + 0.707v_{C/A}$$

$$0 = 1.20 + 0.707v_{C/A}$$

$$v_C = 2.40 \text{ m/s} \qquad \textbf{Ans}$$

$$v_{C/A} = -1.697 \text{ m/s}$$

$$\mathbf{a}_C = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{C/A} + \Omega \times (\Omega \times \mathbf{r}_{C/A}) + 2\Omega \times (\mathbf{v}_{C/A})_{xyz} + (\mathbf{a}_{C/A})_{xyz}$$

$$-(a_C)_t\mathbf{i} - \frac{(2.40)^2}{0.4}\mathbf{j} = 0 + 0 + 3\mathbf{k} \times [3\mathbf{k} \times (0.4\mathbf{i} + 0.4\mathbf{j})] + 2(3\mathbf{k}) \times [0.707(-1.69$$
$$+ 0.707(-1.697)\mathbf{j}] + 0.707a_{C/A}\mathbf{i} + 0.707a_{C/A}\mathbf{j}$$

$$-(a_C)_t\mathbf{i} - 14.40\mathbf{j} = 0 + 0 - 3.60\mathbf{i} - 3.60\mathbf{j} + 7.20\mathbf{i} - 7.20\mathbf{j} + 0.707a_{C/A}\mathbf{i} + 0.707a_C$$

$$-(a_C)_t = -3.60 + 7.20 + 0.707\,a_{C/A}$$

$$-14.40 = -3.60 - 7.20 + 0.707a_{C/A}$$

$$a_{C/A} = -5.09 \text{ m/s}^2$$

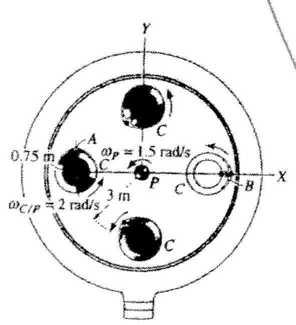
$$(a_C)_t = 0$$

Thus,

$$a_C = (a_C)_n = \frac{(2.40)^2}{0.4} = 14.4 \text{ m/s}^2$$

$$a_C = \{-14.4\mathbf{j}\} \text{ m/s}^2 \qquad \textbf{Ans}$$

***16-140.** A ride in an amusement park consists of a rotating platform P, having a constant angular velocity $\omega_P = 1.5$ rad/s, and four cars, C, mounted on the platform, which have constant angular velocities $\omega_{C/P} = 2$ rad/s measured relative to the platform. Determine the velocity and acceleration of the passenger at B at the instant shown.



Motion of moving reference.

Fix the x,y,z axes to the platform with the origin at O.

$$\mathbf{v}_O = (1.5)(3)\mathbf{j} = 4.5\mathbf{j}$$

$$\mathbf{a}_O = (a_C)_n = -(1.5)^2(3)\mathbf{i} = -6.75\mathbf{i}$$

$$\Omega = 1.5\mathbf{k}$$

$$\dot{\Omega} = 0$$

Motion of A with respect to moving reference.

$$\mathbf{r}_{A/O} = 0.75\mathbf{j}$$

$$(\mathbf{v}_{A/O})_{xyz} = 2(0.75)\mathbf{j} = 1.5\mathbf{j}$$

$$(\mathbf{a}_{A/O})_{xyz} = (a_{A/O})_n = -(2)^2(0.75)\mathbf{i} = -3\mathbf{i}$$

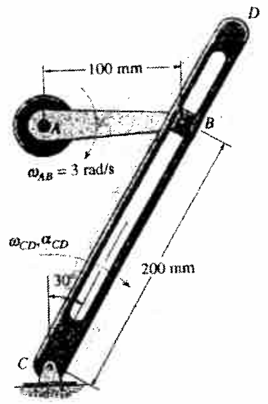
$$\mathbf{v}_B = \mathbf{v}_O + \Omega \times \mathbf{r}_{B/O} + (\mathbf{v}_{B/O})_{xyz}$$
$$= 4.5\mathbf{j} + (1.5\mathbf{k}) \times (0.75\mathbf{j}) + 1.5\mathbf{j}$$

$$\mathbf{v}_B = \{7.12\mathbf{j}\} \text{ m/s} \qquad \textbf{Ans}$$

$$\mathbf{a}_B = \mathbf{a}_O + \dot{\Omega} \times \mathbf{r}_{B/O} + \Omega \times (\Omega \times \mathbf{r}_{B/O}) + 2\Omega \times (\mathbf{v}_{B/O})_{xyz} + (\mathbf{a}_{B/O})_{xyz}$$
$$= -6.75\mathbf{i} + 0 + 1.5\mathbf{k} \times [(1.5\mathbf{k}) \times (0.75\mathbf{i})] + 2(1.5\mathbf{k}) \times (1.5\mathbf{j})] - 3\mathbf{i}$$

$$\mathbf{a}_B = \{-15.9\mathbf{i}\} \text{ m/s}^2 \qquad \textbf{Ans}$$

16-141. Block B of the mechanism is confined to move within the slot member CD. If AB is rotating at a constant rate of $\omega_{AB} = 3$ rad/s, determine the angular velocity and angular acceleration of member CD at the instant shown.



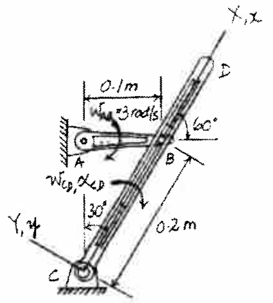
Coordinate Axes : The origin of both the fixed and moving frames of reference are located at point C. The x, y, z moving frame is attached to and rotates with rod CD since peg B slides along the slot in member CD.

Kinematic Equation : Applying Eqs. 16 – 24 and 16 – 27, we have

$$\mathbf{v}_B = \mathbf{v}_C + \Omega \times \mathbf{r}_{B/C} + (\mathbf{v}_{B/C})_{xyz} \qquad [1]$$

$$\mathbf{a}_B = \mathbf{a}_C + \dot{\Omega} \times \mathbf{r}_{B/C} + \Omega \times (\Omega \times \mathbf{r}_{B/C}) + 2\Omega \times (\mathbf{v}_{B/C})_{xyz} + (\mathbf{a}_{B/C})_{xyz} \qquad [2]$$

Motion of moving reference	Motion of C with respect to moving reference
$\mathbf{v}_C = \mathbf{0}$	$\mathbf{r}_{B/C} = \{0.2\mathbf{i}\}$ m
$\mathbf{a}_C = \mathbf{0}$	$(\mathbf{v}_{B/C})_{xyz} = (v_{B/C})_{xyz}\mathbf{i}$
$\Omega = -\omega_{CD}\mathbf{k}$	$(\mathbf{a}_{B/C})_{xyz} = (a_{B/C})_{xyz}\mathbf{i}$
$\dot{\Omega} = -\alpha_{CD}\mathbf{k}$	



The velocity and acceleration of peg B can be determined using Eqs. 16 – 9 and 16 – 14 with $\mathbf{r}_{B/A} = \{0.1\cos 60°\mathbf{i} - 0.1\sin 60°\mathbf{j}\}$ m $= \{0.05\mathbf{i} - 0.08660\mathbf{j}\}$ m.

$$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A} = -3\mathbf{k} \times (0.05\mathbf{i} - 0.08660\mathbf{j}) = \{-0.2598\mathbf{i} - 0.150\mathbf{j}\} \text{ m/s}$$

$$\mathbf{a}_B = \alpha_{AB} \times \mathbf{r}_{B/A} - \omega_{AB}^2 \mathbf{r}_{B/A} = \mathbf{0} - 3^2(0.05\mathbf{i} - 0.08660\mathbf{j}) = \{-0.450\mathbf{i} + 0.7794\mathbf{j}\} \text{ m/s}$$

Substitute the above data into Eq.[1] yields

$$\mathbf{v}_B = \mathbf{v}_C + \Omega \times \mathbf{r}_{B/C} + (\mathbf{v}_{B/C})_{xyz}$$
$$-0.2598\mathbf{i} - 0.150\mathbf{j} = \mathbf{0} + (-\omega_{CD}\mathbf{k}) \times 0.2\mathbf{i} + (v_{B/C})_{xyz}\mathbf{i}$$
$$-0.2598\mathbf{i} - 0.150\mathbf{j} = (v_{B/C})_{xyz}\mathbf{i} - 0.2\omega_{CD}\mathbf{j}$$

Equating $\mathbf{i}$ and $\mathbf{j}$ components, we have

$$(v_{B/C})_{xyz} = -0.2598 \text{ m/s}$$
$$\omega_{CD} = 0.750 \text{ rad/s} \qquad \textbf{Ans}$$

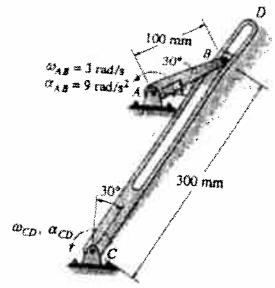
Substitute the above data into Eq.[2] yields

$$\mathbf{a}_B = \mathbf{a}_C + \dot{\Omega} \times \mathbf{r}_{B/C} + \Omega \times (\Omega \times \mathbf{r}_{B/C}) + 2\Omega \times (\mathbf{v}_{B/C})_{xyz} + (\mathbf{a}_{B/C})_{xyz}$$
$$-0.450\mathbf{i} + 0.7794\mathbf{j} = \mathbf{0} + (-\alpha_{CD}\mathbf{k}) \times 0.2\mathbf{i} + (-0.750\mathbf{k}) \times [(-0.750\mathbf{k}) \times 0.2\mathbf{i}] + 2(-0.750\mathbf{k}) \times (-0.2598\mathbf{i}) + (a_{B/C})_{xyz}\mathbf{i}$$
$$-0.450\mathbf{i} + 0.7794\mathbf{j} = \left[(a_{B/C})_{xyz} - 0.1125\right]\mathbf{i} + (0.3897 - 0.2\alpha_{CD})\mathbf{j}$$

Equating $\mathbf{i}$ and $\mathbf{j}$ components, we have

$$(a_{B/C})_{xyz} = -0.3375 \text{ m/s}^2$$
$$\alpha_{CD} = -1.95 \text{ rad/s}^2 = 1.95 \text{ rad/s}^2 \qquad \textbf{Ans}$$

16-142. The "quick-return mechanism" consists of a crank AB, slider block B, and slotted link CD. If the crank has the angular motions shown, determine the angular motions of the slotted link at this instant.



$v_B = 3(0.1) = 0.3$ m/s

$(a_B)_t = 9(0.1) = 0.9$ m/s²

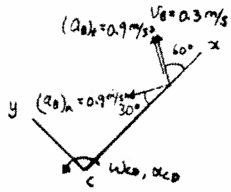
$(a_B)_n = (3)^2(0.1) = 0.9$ m/s²

$\mathbf{v}_B = \mathbf{v}_C + \mathbf{\Omega}\times\mathbf{r}_{B/C} + (\mathbf{v}_{B/C})_{xyz}$

$0.3\cos 60°\mathbf{i} + 0.3\sin 60°\mathbf{j} = \mathbf{0} + (\omega_{CD}\mathbf{k})\times(0.3\mathbf{i}) + v_{B/C}\mathbf{i}$

$v_{B/C} = 0.15$ m/s

$\omega_{CD} = 0.866$ rad/s ↺ **Ans**



$\mathbf{a}_B = \mathbf{a}_C + \dot{\mathbf{\Omega}}\times\mathbf{r}_{B/C} + \mathbf{\Omega}\times(\mathbf{\Omega}\times\mathbf{r}_{B/C}) + 2\mathbf{\Omega}\times(\mathbf{v}_{B/C})_{xyz} + (\mathbf{a}_{B/C})_{xyz}$

$0.9\cos 60°\mathbf{i} - 0.9\cos 30°\mathbf{i} + 0.9\sin 60°\mathbf{j} + 0.9\sin 30°\mathbf{j} = \mathbf{0} + (\alpha_{CD}\mathbf{k})\times(0.3\mathbf{i})$

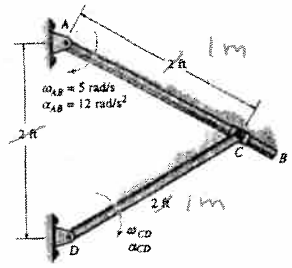
$+(0.866\mathbf{k})\times(0.866\mathbf{k}\times 0.3\mathbf{i}) + 2(0.866\mathbf{k}\times 0.15\mathbf{i}) + a_{B/C}\mathbf{i}$

$-0.3294\mathbf{i} + 1.2294\mathbf{j} = 0.3\alpha_{CD}\mathbf{j} - 0.225\mathbf{i} + 0.2598\mathbf{j} + a_{B/C}\mathbf{i}$

$a_{B/C} = -0.104$ m/s²

$\alpha_{CD} = 3.23$ rad/s² ↺ **Ans**

16-143. At a given instant, rod AB has the angular motions shown. Determine the angular velocity and angular acceleration of rod CD at this instant. There is a collar at C.



$v_A = 0$

$a_A = 0$

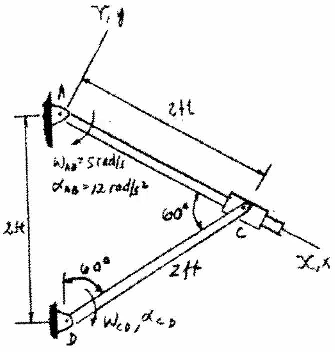
$\Omega = \{-5\mathbf{k}\}$ rad/s

$\dot{\Omega} = \{-12\mathbf{k}\}$ rad/s²

$\mathbf{r}_{C/A} = \cancel{\{2\mathbf{i}\}\text{ ft}}$ $\{1\mathbf{i}\}$ m

$(\mathbf{v}_{C/A})_{xyz} = (v_{C/A})_{xyz}\mathbf{i}$

$(\mathbf{a}_{C/A})_{xyz} = (a_{C/A})_{xyz}\mathbf{i}$



$\mathbf{v}_C = \mathbf{v}_A + \Omega\times\mathbf{r}_{C/A} + (\mathbf{v}_{C/A})_{xyz}$

$\mathbf{v}_C = 0 + (-5\mathbf{k})\times(\cancel{2}\mathbf{i}) + (v_{C/A})_{xyz}\mathbf{i}$

$= (v_{C/A})_{xyz}\mathbf{i} - \overset{5}{\cancel{10}}\mathbf{j}$

$\mathbf{v}_C = \omega_{CD}\times\mathbf{r}_{CD}$

$(v_{C/A})_{xyz}\mathbf{i} - \overset{5}{\cancel{10}}\mathbf{j} = (-\omega_{CD}\mathbf{k})\times(\cancel{2}\cos 60°\mathbf{i} + \cancel{2}\sin 60°\mathbf{j})$

$(v_{C/A})_{xyz}\mathbf{i} - \overset{5}{\cancel{10}}\mathbf{j} = 1.732\omega_{CD}\mathbf{i} - \omega_{CD}\mathbf{j}$

$= 0.866\,\omega_{CD}\,i - 0.5\,\omega_{CD}\,j$

Solving :

$\omega_{CD} = 10$ rad/s ⟳ ✓ **Ans**

$(v_{C/A})_{xyz} = \overset{0.866}{\cancel{1.732}}(10) = \cancel{17.32\text{ ft/s}}$ 8.66 m/s

$\mathbf{a}_C = \mathbf{a}_A + \dot{\Omega}\times\mathbf{r}_{C/A} + \Omega\times(\Omega\times\mathbf{r}_{C/A}) + 2\Omega\times(\mathbf{v}_{C/A})_{xyz} + (\mathbf{a}_{C/A})_{xyz}$

$\mathbf{a}_C = 0 + (-12\mathbf{k})\times(\cancel{2}\mathbf{i}) + (-5\mathbf{k})\times\left[(-5\mathbf{k})\times(\cancel{2}\mathbf{i})\right] + 2(-5\mathbf{k})\times\left[(v_{C/A})_{xyz}\mathbf{i}\right] + (a_{C/A})_{xyz}\mathbf{i}$

$= \left[(a_{C/A})_{xyz} - \overset{25}{\cancel{50}}\right]\mathbf{i} - \left[10(v_{C/A})_{xyz} + \overset{12}{\cancel{24}}\right]\mathbf{j}$

$\mathbf{a}_C = \alpha_{CD}\times\mathbf{r}_{C/D} - \omega_{CD}^2\mathbf{r}_{C/D}$

$\left[(a_{C/A})_{xyz} - \overset{25}{\cancel{50}}\right]\mathbf{i} - \left[10(\overset{8.66}{\cancel{17.32}}) + \overset{12}{\cancel{24}}\right]\mathbf{j} = (-\alpha_{CD}\mathbf{k})\times(\overset{1}{\cancel{2}}\cos 60°\mathbf{i} + \overset{1}{\cancel{2}}\sin 60°\mathbf{j})$

$- (10)^2(\overset{1}{\cancel{2}}\cos 60°\mathbf{i} + \overset{1}{\cancel{2}}\sin 60°\mathbf{j})$

$\left[(a_{C/A})_{xyz} - \overset{25}{\cancel{50}}\right]\mathbf{i} - \left[10(\overset{8.66}{\cancel{17.32}}) + \overset{12}{\cancel{24}}\right]\mathbf{j} = (\underset{0.866}{\cancel{1.732}}\alpha_{CD} - \underset{50}{\cancel{100}})\mathbf{i} - (\alpha_{CD} + \underset{86.6}{\cancel{173.2}})\mathbf{j}$

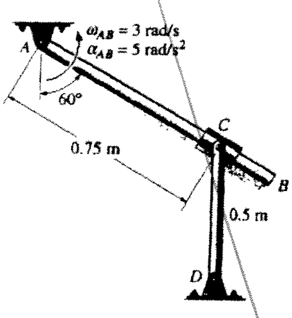
Solving :

$-\left[10(\overset{8.66}{\cancel{17.32}}) + \overset{12}{\cancel{24}}\right] = -(\alpha_{CD} + \overset{86.6}{\cancel{173.2}})$ $\alpha_{CD} = \overset{12}{\cancel{24}}$ rad/s² ⟳ ✓ **Ans**

$(a_{C/A})_{xyz} - \overset{25}{\cancel{50}} = \cancel{1.732(24) - 100}$ $(a_{C/A})_{xyz} = \cancel{-8.43\text{ ft/s}^2}$

$0.866(12) - 50$ $= -14.61$ m/s²

***16-144.** At the instant shown rod AB has an angular velocity $\omega_{AB} = 3\text{ rad/s}$ and an angular acceleration $\alpha_{AB} = 5\text{ rad/s}^2$. Determine the angular velocity and angular acceleration of rod CD at this instant. The collar at C is pin-connected to CD and slides over AB.



$$\mathbf{r}_{C/A} = (0.75\sin 60°)\mathbf{i} - (0.75\cos 60°)\mathbf{j}$$

$$\mathbf{r}_{C/A} = \{0.6495\mathbf{i} - 0.375\mathbf{j}\}\text{ m}$$

$$\mathbf{v}_C = \omega_{CD} \times \mathbf{r}_{C/D}$$

$$= (\omega_{CD}\mathbf{k}) \times (0.5\mathbf{j})$$

$$= \{-0.5\omega_{CD}\mathbf{i}\}\text{ m/s}$$

$$\mathbf{a}_C = \alpha_{CD} \times \mathbf{r}_{CD} - \omega_{CD}^2 \mathbf{r}_{CD}$$

$$= (\alpha_{CD}\mathbf{k}) \times (0.5\mathbf{j}) - \omega_{CD}^2(0.5\mathbf{j})$$

$$a_C = \{-0.5\alpha_{CD}\mathbf{i} - \omega_{CD}^2(0.5)\mathbf{j}\}\text{ m/s}^2$$

$$\mathbf{v}_C = \mathbf{v}_A + \boldsymbol{\Omega} \times \mathbf{r}_{C/A} + (\mathbf{v}_{C/A})_{xyz}$$

$$-0.5\omega_{CD}\mathbf{i} = 0 + (3\mathbf{k}) \times (0.6495\mathbf{i} - 0.375\mathbf{j}) + v_{C/A}\sin 60°\mathbf{i} - v_{C/A}\cos 60°\mathbf{j}$$

$$-0.5\omega_{CD} = 1.125 + 0.866 v_{C/A}$$

$$0 = 1.9485 - 0.5 v_{C/A}$$

$$v_{C/A} = 3.897\text{ m/s}$$

$$\omega_{CD} = -9.00\text{ rad/s} = 9.00\text{ rad/s} \qquad \textbf{Ans}$$

$$\mathbf{a}_C = \mathbf{a}_A + \dot{\boldsymbol{\Omega}} \times \mathbf{r}_{C/A} + \boldsymbol{\Omega} \times (\boldsymbol{\Omega} \times \mathbf{r}_{C/A}) + 2\boldsymbol{\Omega} \times (\mathbf{v}_{C/A})_{xyz} + (\mathbf{a}_{C/A})_{xyz}$$

$$\mathbf{a}_C = 0 + (5\mathbf{k}) \times (0.6495\mathbf{i} - 0.375\mathbf{j}) + (3\mathbf{k}) \times [(3\mathbf{k}) \times (0.6495\mathbf{i} - 0.375\mathbf{j})]$$
$$+ 2(3\mathbf{k}) \times [3.897(0.866)\mathbf{i} - 0.5(3.897)\mathbf{j}] + 0.866 a_{C/A}\mathbf{i} - 0.5 a_{C/A}\mathbf{j}$$

$$0.5\alpha_{CD}\mathbf{i} - (-9.00)^2(0.5)\mathbf{j} = 0 + 1.875\mathbf{i} + 3.2475\mathbf{j} - 5.8455\mathbf{i} + 3.375\mathbf{j} + 11.6910\mathbf{i}$$
$$+ 20.2488\mathbf{j} + 0.866 a_{C/A}\mathbf{i} - 0.5 a_{C/A}\mathbf{j}$$

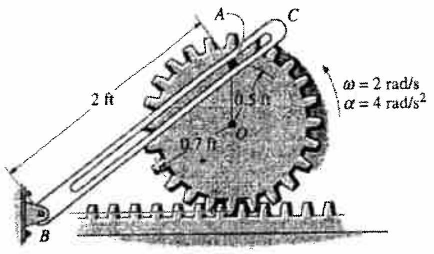
$$0.5\alpha_{CD} = 7.7205 + 0.866 a_{C/A}$$

$$-40.5 = 26.8713 - 0.5 a_{C/A}$$

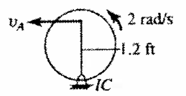
$$a_{C/A} = 134.7\text{ m/s}^2$$

$$\alpha_{CD} = 249\text{ rad/s}^2 \qquad \textbf{Ans}$$

16-145. The gear has the angular motion shown. Determine the angular velocity and angular acceleration of the slotted link BC at this instant. The peg at A is fixed to the gear.



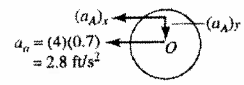
$v_A = (1.2)(2) = 2.4 \text{ ft/s} \leftarrow$



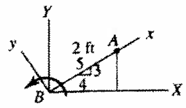
$a_O = 4(0.7) = 2.8 \text{ ft/s}^2$

$\mathbf{a}_A = \mathbf{a}_O + \mathbf{a}_{A/O}$

$\mathbf{a}_A = \underset{\leftarrow}{2.8} + \underset{\leftarrow}{4(0.5)} + \underset{\downarrow}{(2)^2(0.5)}$



$\mathbf{a}_A = \underset{\leftarrow}{4.8} + \underset{\downarrow}{2}$



$\mathbf{v}_A = \mathbf{v}_B + \Omega \times \mathbf{r}_{A/B} + (\mathbf{v}_{A/B})_{xyz}$

$-2.4\mathbf{i} = 0 + (\Omega\mathbf{k}) \times (1.6\mathbf{i} + 1.2\mathbf{j}) + v_{A/B}\left(\frac{4}{5}\right)\mathbf{i} + v_{A/B}\left(\frac{3}{5}\right)\mathbf{j}$

$-2.4\mathbf{i} = 1.6\Omega\mathbf{j} - 1.2\Omega\mathbf{i} + 0.8v_{A/B}\mathbf{i} + 0.6v_{A/B}\mathbf{j}$

$-2.4 = -1.2\Omega + 0.8v_{A/B}$

$0 = 1.6\Omega + 0.6v_{A/B}$

Solving,

$\omega_{BC} = \Omega = 0.720 \text{ rad/s} \circlearrowleft$ **Ans**

$v_{A/B} = -1.92 \text{ ft/s}$

$\mathbf{a}_A = \mathbf{a}_B + \dot{\Omega} \times \mathbf{r}_{A/B} + \Omega \times (\Omega \times \mathbf{r}_{A/B}) + 2\Omega \times (\mathbf{v}_{A/B})_{xyz} + (\mathbf{a}_{A/B})_{xyz}$

$-4.8\mathbf{i} - 2\mathbf{j} = 0 + (\dot{\Omega}\mathbf{k}) \times (1.6\mathbf{i} + 1.2\mathbf{j}) + (0.72\mathbf{k}) \times (0.72\mathbf{k} \times (1.6\mathbf{i} + 1.2\mathbf{j}))$

$+ 2(0.72\mathbf{k}) \times [-(0.8)(1.92)\mathbf{i} - 0.6(1.92)\mathbf{j}] + 0.8a_{B/A}\mathbf{i} + 0.6a_{B/A}\mathbf{j}$

$-4.8\mathbf{i} - 2\mathbf{j} = 1.6\dot{\Omega}\mathbf{j} - 1.2\dot{\Omega}\mathbf{i} - 0.8294\mathbf{i} - 0.6221\mathbf{j} - 2.2118\mathbf{j} + 1.6589\mathbf{i} + 0.8a_{B/A}\mathbf{i} + 0.6a_{B/A}.$

$-4.8 = -1.2\dot{\Omega} - 0.8294 + 1.6589 + 0.8a_{B/A}$

$-2 = 1.6\dot{\Omega} - 0.6221 - 2.2118 + 0.6a_{B/A}$

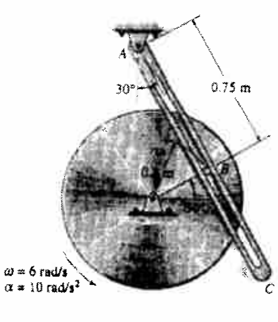
$-4.6913 = -\dot{\Omega} + 0.667a_{B/A}$

$0.5212 = \dot{\Omega} + 0.357a_{B/A}$

$\alpha_{BC} = \dot{\Omega} = 2.02 \text{ rad/s}^2 \circlearrowleft$ **Ans**

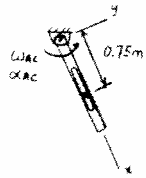
$a_{B/A} = -4.00 \text{ ft/s}^2$

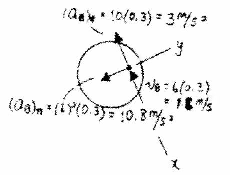
16-146. The disk rotates with the angular motion shown. Determine the angular velocity and angular acceleration of the slotted link AC at this instant. The peg at B is fixed to the disk.



$\mathbf{v}_B = -6(0.3)\mathbf{i} = -1.8\mathbf{i}$

$\mathbf{a}_B = -10(0.3)\mathbf{i} - (6)^2(0.3)\mathbf{j} = -3\mathbf{i} - 10.8\mathbf{j}$





$\mathbf{v}_B = \mathbf{v}_A + \Omega \times \mathbf{r}_{B/A} + (\mathbf{v}_{B/A})_{xyz}$

$-1.8\mathbf{i} = \mathbf{0} + (\omega_{AC}\mathbf{k}) \times (0.75\mathbf{i}) - (v_{B/A})_{xyz}\,\mathbf{i}$

$-1.8\mathbf{i} = -(v_{B/A})_{xyz}$

$(v_{B/A})_{xyz} = 1.8$ m/s

$0 = \omega_{AC}(0.75)$

$\omega_{AC} = 0$ **Ans**

$\mathbf{a}_B = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{B/A} + \Omega \times (\Omega \times \mathbf{r}_{B/A}) + 2\Omega \times (\mathbf{v}_{B/A})_{xyz} + (\mathbf{a}_{B/A})_{xyz}$

$-3\mathbf{i} - 10.8\mathbf{j} = \mathbf{0} + \alpha_{AC}\mathbf{k} \times (0.75\mathbf{i}) + \mathbf{0} + \mathbf{0} - a_{A/B}\,\mathbf{i}$

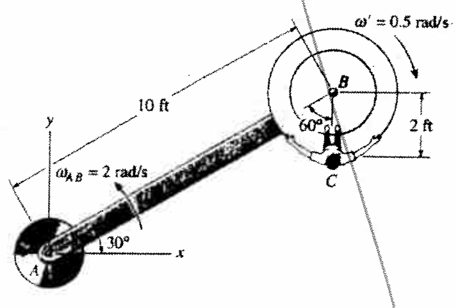
$-3 = -a_{A/B}$

$a_{A/B} = 3$ m/s²

$-10.8 = \alpha_{AC}(0.75)$

$\alpha_{AC} = 14.4$ rad/s² ↻ **Ans**

16-147. A ride in an amusement park consists of a rotating arm AB having a constant angular velocity $\omega_{AB} = 2$ rad/s about point A and a car mounted at the end of the arm which has a constant angular velocity $\boldsymbol{\omega}' = \{-0.5\mathbf{k}\}$ rad/s, measured relative to the arm. At the instant shown, determine the velocity and acceleration of the passenger at C.



$\mathbf{r}_{B/A} = (10\cos 30°\mathbf{i} + 10\sin 30°\mathbf{j}) = \{8.66\mathbf{i} + 5\mathbf{j}\}$ ft

$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A} = 2\mathbf{k} \times (8.66\mathbf{i} + 5\mathbf{j}) = \{-10.0\mathbf{i} + 17.32\mathbf{j}\}$ ft/s

$\mathbf{a}_B = \alpha_{AB} \times \mathbf{r}_{B/A} - \omega_{AB}^2\mathbf{r}_{B/A}$

$= 0 - (2)^2(8.66\mathbf{i} + 5\mathbf{j}) = \{-34.64\mathbf{i} - 20\mathbf{j}\}$ ft/s²

$\Omega = (2 - 0.5)\mathbf{k} = 1.5\mathbf{k}$

$\mathbf{v}_C = \mathbf{v}_B + \Omega \times \mathbf{r}_{C/B} + (\mathbf{v}_{C/B})_{xyz}$

$= -10.0\mathbf{i} + 17.32\mathbf{j} + 1.5\mathbf{k} \times (-2\mathbf{j}) + 0$

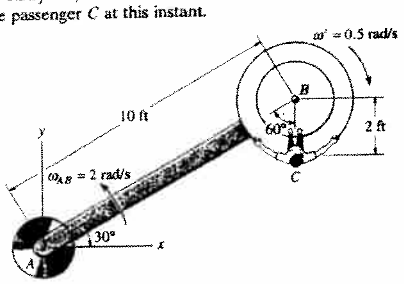
$= \{-7.00\mathbf{i} + 17.3\mathbf{j}\}$ ft/s **Ans**

$\mathbf{a}_C = \mathbf{a}_B + \dot{\Omega} \times \mathbf{r}_{C/B} + \Omega \times (\Omega \times \mathbf{r}_{C/B}) + 2\Omega \times (\mathbf{v}_{C/B})_{xyz} + (\mathbf{a}_{C/B})_{xyz}$

$= -34.64\mathbf{i} - 20\mathbf{j} + 0 + (1.5\mathbf{k}) \times (1.5\mathbf{k}) \times (-2\mathbf{j}) + 0 + 0$

$= \{-34.6\mathbf{i} - 15.5\mathbf{j}\}$ ft/s² **Ans**

***16-148.** A ride in an amusement park consists of a rotating arm AB that has an angular acceleration of $\alpha_{AB} = 1\ \text{rad/s}^2$ when $\omega_{AB} = 2$ rad/s at the instant shown. Also at this instant the car mounted at the end of the arm has a relative angular acceleration of $\boldsymbol{\alpha}' = \{-0.6\mathbf{k}\}\ \text{rad/s}^2$ when $\boldsymbol{\omega}' = \{-0.5\mathbf{k}\}$ rad/s. Determine the velocity and acceleration of the passenger C at this instant.



$$\mathbf{r}_{B/A} = (10\cos 30°\mathbf{i} + 10\sin 30°\mathbf{j}) = \{8.66\mathbf{i} + 5\mathbf{j}\}\ \text{ft}$$

$$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A} = 2\mathbf{k} \times (8.66\mathbf{i} + 5\mathbf{j}) = \{-10.0\mathbf{i} + 17.32\mathbf{j}\}\ \text{ft/s}$$

$$\mathbf{a}_B = \alpha_{AB} \times \mathbf{r}_{B/A} - \omega_{AB}^2 \mathbf{r}_{B/A}$$

$$= (1\mathbf{k}) \times (8.66\mathbf{i} + 5\mathbf{j}) - (2)^2(8.66\mathbf{i} + 5\mathbf{j}) = \{-39.64\mathbf{i} - 11.34\mathbf{j}\}\ \text{ft/s}^2$$

$$\Omega = (2 - 0.5)\mathbf{k} = 1.5\mathbf{k}$$

$$\dot{\Omega} = (1 - 0.6)\mathbf{k} = 0.4\mathbf{k}$$

$$\mathbf{v}_C = \mathbf{v}_B + \Omega \times \mathbf{r}_{C/B} + (\mathbf{v}_{C/B})_{xyz}$$

$$= -10.0\mathbf{i} + 17.32\mathbf{j} + 1.5\mathbf{k} \times (-2\mathbf{j}) + 0$$

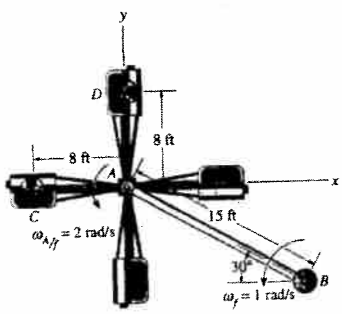
$$= \{-7.00\mathbf{i} + 17.3\mathbf{j}\}\ \text{ft/s} \qquad \textbf{Ans}$$

$$\mathbf{a}_C = \mathbf{a}_B + \dot{\Omega} \times \mathbf{r}_{C/B} + \Omega \times (\Omega \times \mathbf{r}_{C/B}) + 2\Omega \times (\mathbf{v}_{C/B})_{xyz} + (\mathbf{a}_{C/B})_{xyz}$$

$$= -39.64\mathbf{i} - 11.34\mathbf{j} + (0.4\mathbf{k}) \times (-2\mathbf{j}) + (1.5\mathbf{k}) \times (1.5\mathbf{k}) \times (-2\mathbf{j}) + 0 + 0$$

$$= \{-38.8\mathbf{i} - 6.84\mathbf{j}\}\ \text{ft/s}^2 \qquad \textbf{Ans}$$

16-149. The cars on the amusement-park ride rotate around the axle at A with a constant angular velocity $\omega_{A/f} = 2$ rad/s, measured relative to the frame AB. At the same time the frame rotates around the main axle support at B with a constant angular velocity $\omega_f = 1$ rad/s. Determine the velocity and acceleration of the passenger at C at the instant shown.



$$\mathbf{v}_C = \mathbf{v}_A + \Omega \times \mathbf{r}_{C/A} + (\mathbf{v}_{C/A})_{xyz} \qquad [1]$$

$$\mathbf{a}_C = \mathbf{a}_A + \dot{\Omega} \times \mathbf{r}_{C/A} + \Omega \times (\Omega \times \mathbf{r}_{C/A}) + 2\Omega \times (\mathbf{v}_{C/A})_{xyz} + (\mathbf{a}_{C/A})_{xyz} \qquad [2]$$

Motion of moving reference

$\Omega = \{3\mathbf{k}\}$ rad/s

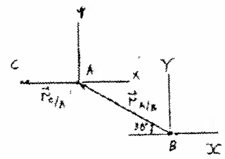
$\dot{\Omega} = 0$

Motion of C with respect to moving reference

$\mathbf{r}_{C/A} = \{-8\mathbf{i}\}$ ft

$(\mathbf{v}_{C/A})_{xyz} = 0$

$(\mathbf{a}_{C/A})_{xyz} = 0$



Motion of A :

$$\mathbf{v}_A = \omega \times \mathbf{r}_{A/B}$$

$$= (1\mathbf{k}) \times (-15\cos 30°\mathbf{i} + 15\sin 30°\mathbf{j})$$

$$= \{-7.5\mathbf{i} - 12.99\mathbf{j}\}\ \text{ft/s}$$

$$\mathbf{a}_A = \alpha \times \mathbf{r}_{A/B} - \omega^2 \mathbf{r}_{A/B}$$

$$= 0 - (1)^2(-15\cos 30°\mathbf{i} + 15\sin 30°\mathbf{j})$$

$$= \{12.99\mathbf{i} - 7.5\mathbf{j}\}\ \text{ft/s}^2$$

Substitute the data into Eqs.[1] and [2] yields :

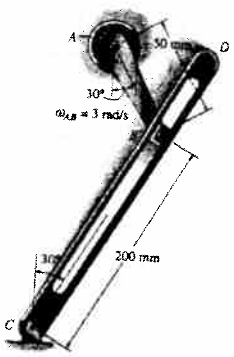
$$\mathbf{v}_C = (-7.5\mathbf{i} - 12.99\mathbf{j}) + (3\mathbf{k}) \times (-8\mathbf{i}) + 0$$

$$= \{-7.5\mathbf{i} - 37.0\mathbf{j}\}\ \text{ft/s} \qquad \textbf{Ans}$$

$$\mathbf{a}_C = (12.99\mathbf{i} - 7.5\mathbf{j}) + 0 + (3\mathbf{k}) \times [(3\mathbf{k}) \times (-8\mathbf{i})] + 0 + 0$$

$$= \{85.0\mathbf{i} - 7.5\mathbf{j}\}\ \text{ft/s}^2 \qquad \textbf{Ans}$$

16–150. The block B of the quick-return mechanism is confined to move within the slot in member CD. If AB is rotating at a constant rate of $\omega_{AB} = 3$ rad/s, determine the angular velocity and angular acceleration of member CD at the instant shown.



$\mathbf{v}_C = \mathbf{0}$

$\mathbf{a}_C = \mathbf{0}$

$\mathbf{\Omega} = -\omega_{CD}\mathbf{k}$

$\dot{\mathbf{\Omega}} = \alpha_{CD}\mathbf{k}$

$\mathbf{r}_{B/C} = \{0.2\mathbf{i}\}$ m

$(\mathbf{v}_{B/C})_{xyz} = (v_{B/C})_{xyz}\mathbf{i}$

$(\mathbf{a}_{B/C})_{xyz} = (a_{B/C})_{xyz}\mathbf{i}$

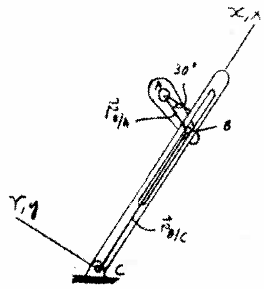
$\mathbf{v}_B = \omega_{AB} \times \mathbf{r}_{B/A} = (3\mathbf{k}) \times (-0.05\sin 30°\mathbf{i} - 0.05\cos 30°\mathbf{j})$

$= \{0.1299\mathbf{i} - 0.075\mathbf{j}\}$ m/s

$\mathbf{a}_B = \alpha_{AB} \times \mathbf{r}_{B/A} - \omega_{AB}^2 \mathbf{r}_{B/A}$

$= \mathbf{0} - (3)^2(-0.05\sin 30°\mathbf{i} - 0.05\cos 30°\mathbf{j})$

$= \{0.225\mathbf{i} + 0.3897\mathbf{j}\}$ m/s^2



$\mathbf{v}_B = \mathbf{v}_C + \mathbf{\Omega} \times \mathbf{r}_{B/C} + (\mathbf{v}_{B/C})_{xyz}$

$0.1299\mathbf{i} - 0.075\mathbf{j} = \mathbf{0} + (-\omega_{CD}\mathbf{k}) \times (0.2\mathbf{i}) + (v_{B/C})_{xyz}\mathbf{i}$

$0.1299\mathbf{i} - 0.075\mathbf{j} = (v_{B/C})_{rel}\mathbf{i} - 0.2\omega_{CD}\mathbf{j}$

Solving :

$(v_{B/C})_{xyz} = 0.1299$ m/s

$\omega_{CD} = 0.375$ rad/s ↻ **Ans**

$\mathbf{a}_B = \mathbf{a}_C + \dot{\mathbf{\Omega}} \times \mathbf{r}_{B/C} + \mathbf{\Omega} \times (\mathbf{\Omega} \times \mathbf{r}_{B/C}) + 2\mathbf{\Omega} \times (\mathbf{v}_{B/C})_{xyz} + (\mathbf{a}_{B/C})_{xyz}$

$0.225\mathbf{i} + 0.3897\mathbf{j} = \mathbf{0} + (\alpha_{CD}\mathbf{k}) \times (0.2\mathbf{i}) + (-0.375\mathbf{k}) \times [(-0.375\mathbf{k}) \times (0.2\mathbf{i})]$

$+ 2(-0.375\mathbf{k}) \times (0.1299\mathbf{i}) + (a_{B/C})_{xyz}\mathbf{i}$

$0.225\mathbf{i} + 0.3897\mathbf{j} = [(a_{B/C})_{xyz} - 0.028125]\mathbf{i} + (0.2\alpha_{CD} - 0.097428)\mathbf{j}$

Equating the $\mathbf{i}$ and $\mathbf{j}$ components and solving,

$(a_{B/C})_{xyz} = 0.2531$ m/s^2

$\alpha_{CD} = 2.44$ rad/s^2 ↺ **Ans**