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?

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

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

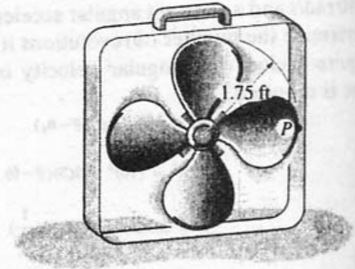
$$\theta = 20.83 \text{ rad} = 20.83\left(\frac{1}{2\pi}\right) = 3.32 \text{ rev.}$$ **Ans**

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

$$15 = 10 + 3t$$

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

***16-4.** Just after the fan is turned on, the motor gives the blade an angular acceleration $\alpha = (20e^{-0.6t})\ \text{rad/s}^2$, where t is in seconds. Determine the speed of the tip P of one of the blades when $t = 3$ s. How many revolutions has the blade turned in 3 s? When $t = 0$ the blade is at rest.



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

$$\int_0^\omega d\omega = \int_0^t 20e^{-0.6t}\, dt$$

$$\omega = -\frac{20}{0.6}e^{-0.6t}\Big|_0^t = 33.3\left(1 - e^{-0.6t}\right)$$

$$\omega = 27.82\ \text{rad/s}$$

$$v_P = \omega r = 27.82(1.75) = 48.7\ \text{ft/s} \qquad \textbf{Ans}$$

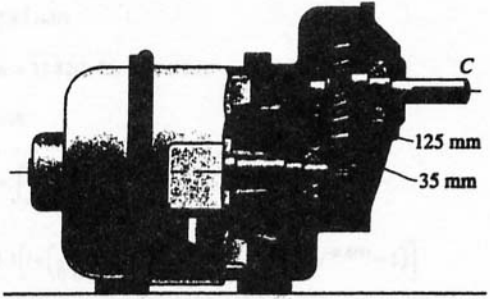
$$d\theta = \omega\, dt$$

$$\int_0^\theta d\theta = \int_0^t 33.3\left(1 - e^{-0.6t}\right) dt$$

$$\theta = 33.3\left(t + \left(\frac{1}{0.6}\right)e^{-0.6t}\right)\Big|_0^3 = 33.3\left[3 + \left(\frac{1}{0.6}\right)\left(e^{-0.6(3)} - 1\right)\right]$$

$$\theta = 53.63\ \text{rad} = 8.54\ \text{rev} \qquad \textbf{Ans}$$

*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.



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

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

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

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

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

$$\omega_A r_A = \omega_B r_B$$

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

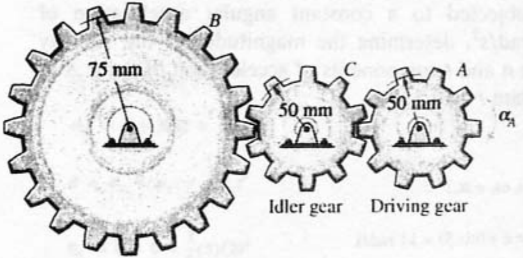
$$\omega_C = \omega_B = 1.68\ \text{rad/s} \qquad \textbf{Ans}$$

$$\theta_A r_A = \theta_B r_B$$

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

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

***16-12.** When only two gears are in mesh, the driving gear A and the driven gear B will always turn in opposite directions. In order to get them to turn in the *same direction* an idler gear C is used. In the case shown, determine the angular velocity of gear B when $t = 5$ s, if gear A starts from rest and has an angular acceleration of $\alpha_A = (3t + 2)$ rad/s^2, where t is in seconds.



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

$$\int_0^{\omega_A} d\omega_A = \int_0^t (3t + 2) \, dt$$

$$\omega_A = 1.5t^2 + 2t\Big|_{t=5} = 47.5 \text{ rad/s}$$

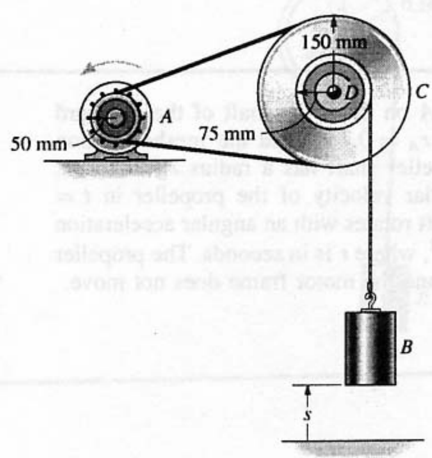
$$(47.5)(50) = \omega_C (50)$$

$$\omega_C = 47.5 \text{ rad/s}$$

$$\omega_B (75) = 47.5(50)$$

$$\omega_B = 31.7 \text{ rad/s} \qquad \textbf{Ans}$$

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, $\alpha_C = 6\theta_C$

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

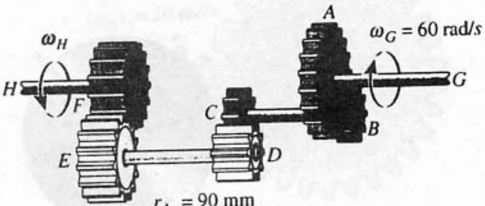
$6\theta_C^2 = \omega_C^2$

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

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

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

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.



$r_A = 90$ mm
$r_B = r_C = 30$ mm
$r_D = 50$ mm
$r_E = 70$ mm
$r_F = 60$ mm

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

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

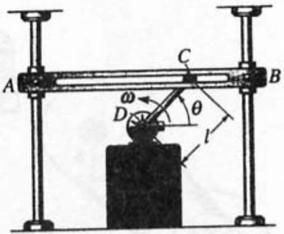
$180(30) = 50(\omega_{DE})$

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

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

$\omega_H = 126$ rad/s **Ans**

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.



$$y = l\sin\theta$$

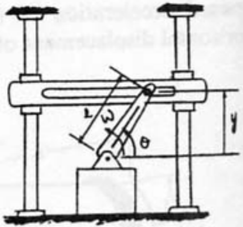
$$\dot{y} = v_y = l\cos\theta\dot{\theta}$$

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

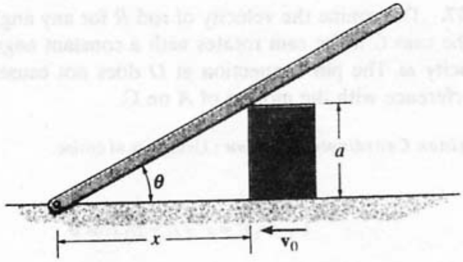
Here $v_y = v_{AB}$, $a_y = a_{AB}$, and $\dot{\theta} = \omega$, $\ddot{\theta} = \alpha = 0$.

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

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

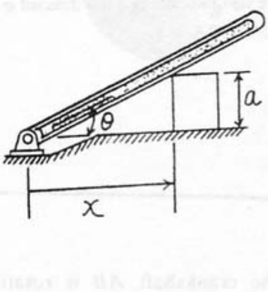


*16-36. The block moves to the left with a constant velocity $\mathbf{v}_0$. Determine the angular velocity and angular acceleration of the bar as a function of θ.



Position Coordinate Equation : From the geometry.

$$x = \frac{a}{\tan\theta} = a\cot\theta \qquad [1]$$



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

$$\frac{dx}{dt} = -a\csc^2\theta\frac{d\theta}{dt} \qquad [2]$$

Since υ_0 is directed toward negative x, then $\frac{dx}{dt} = -\upsilon_0$. Also, $\frac{d\theta}{dt} = \omega$.

From Eq. [2],

$$-\upsilon_0 = -a\csc^2\theta(\omega)$$

$$\omega = \frac{\upsilon_0}{a\csc^2\theta} = \frac{\upsilon_0}{a}\sin^2\theta \qquad \textbf{Ans}$$

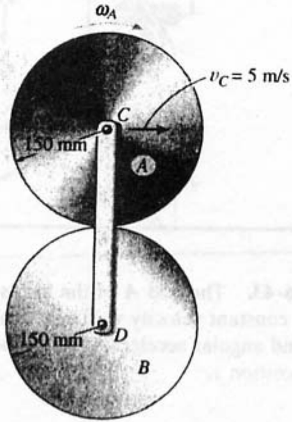
Here, $\alpha = \frac{d\omega}{dt}$. Then from the above expression

$$\alpha = \frac{\upsilon_0}{a}(2\sin\theta\cos\theta)\frac{d\theta}{dt} \qquad [3]$$

However, $2\sin\theta\cos\theta = \sin 2\theta$ and $\omega = \frac{d\theta}{dt} = \frac{\upsilon_0}{a}\sin^2\theta$. Substitute these values into Eq. [3] yields

$$\alpha = \frac{\upsilon_0}{a}\sin 2\theta\left(\frac{\upsilon_0}{a}\sin^2\theta\right) = \left(\frac{\upsilon_0}{a}\right)^2\sin 2\theta\sin^2\theta \qquad \textbf{Ans}$$

***16-40.** Disk *A* rolls without slipping over the surface of the *fixed* cylinder *B*. Determine the angular velocity of *A* if its center *C* has a speed $v_C = 5$ m/s. How many revolutions will *A* have made about its center just after link *DC* completes one revolution?



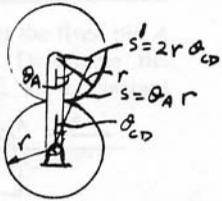
As shown by the construction, as *A* rolls through the arc $s = \theta_A r$, the center of the disk moves through the same distance $s' = s$. Hence,

$s = \theta_A r$

$\dot{s} = \dot{\theta}_A r$

$5 = \omega_A (0.15)$

$\omega_A = 33.3$ rad/s **Ans**



Link :

$s' = 2r\theta_{CD} = s = \theta_A r$

$2\theta_{CD} = \theta_A$

Thus, *A* makes 2 revolutions for each revolution of *CD*. **Ans**