13-36. Determine the acceleration of block A when the system is released. The coefficient of kinetic friction and the weight of each block are indicated. Neglect the mass of the pulleys and cord.

Block A:
\[ \Sigma F_y = m_a a_y \]
\[ N_A - 60 \cos 60^\circ = 0 \]
\[ 90 \sin 60^\circ - 0.2N_A - 2T = \left( \frac{80}{32.2} \right) a_A \]

Block B:
\[ \Sigma F_y = m_a a_y \]
\[ -T + 20 = \left( \frac{20}{32.2} \right) a_B \]
\[ 2a_A + a_B = 0 \]
\[ 2a_A = -a_B \]
Solving,
\[ N_A = 40 \text{ lb} \quad T = 25.32 \text{ lb} \quad a_B = -8.57 \text{ ft/s}^2 \]
\[ a_A = 4.28 \text{ ft/s}^2 \quad \text{Ans} \]

13-37. The conveyor belt is moving at 4 m/s. If the coefficient of static friction between the conveyor and the 10-kg package B is \( \mu_s = 0.2 \), determine the shortest time the belt can stop so that the package does not slide on the belt.

\[ \vec{\Sigma F}_x = m \vec{a} \]
\[ 0.2(98.1) = 10 a \]
\[ a = 1.962 \text{ m/s}^2 \]
\[ \vec{v} = \vec{v}_0 + \vec{a} t \]
\[ \vec{a} = 0 + 1.962 t \]
\[ t = 2.04 \text{ s} \quad \text{Ans} \]
13-42. Blocks A and B each have a mass \( m \). Determine the largest horizontal force \( P \) which can be applied to B so that A will not move relative to B. All surfaces are smooth.

Require:
\[ a_1 = a_2 = a \]

Block A:
\[ \sum F_x = 0; \quad N \cos \theta - mg = 0 \]
\[ \sum F_y = ma; \quad N \sin \theta = ma \]
\[ a = g \tan \theta \]

Block B:
\[ \sum F_x = ma; \quad P - N \sin \theta = ma \]
\[ P - mg \tan \theta = mg \tan \theta \]
\[ P = 2mg \tan \theta \quad \text{Ans} \]

13-43. Blocks A and B each have a mass \( m \). Determine the largest horizontal force \( P \) which can be applied to B so that A will not slip up B. The coefficient of static friction between A and B is \( \mu_s \). Neglect any friction between B and C.

Require:
\[ a_1 = a_2 = a \]

Block A:
\[ \sum F_x = 0; \quad N \cos \theta - \mu_s N \sin \theta - mg = 0 \]
\[ \sum F_y = ma; \quad N \sin \theta + \mu_s N \cos \theta = ma \]
\[ N = \frac{mg}{\cos \theta - \mu_s \sin \theta} \]
\[ a = g \left( \frac{\sin \theta + \mu_s \cos \theta}{\cos \theta - \mu_s \sin \theta} \right) \]

Block B:
\[ \sum F_x = ma; \quad P - \mu_s N \cos \theta - N \sin \theta = ma \]
\[ P - mg \left( \frac{\sin \theta + \mu_s \cos \theta}{\cos \theta - \mu_s \sin \theta} \right) = mg \left( \frac{\sin \theta + \mu_s \cos \theta}{\cos \theta - \mu_s \sin \theta} \right) \]
\[ P = 2mg \left( \frac{\sin \theta + \mu_s \cos \theta}{\cos \theta - \mu_s \sin \theta} \right) \quad \text{Ans} \]
13-95. Solve Prob. 13-94 if the spiral rod is vertical.

\[ r = 29 \]

\[ \omega = \frac{\pi}{2}, \quad \psi = 57.52^\circ \]

\[ \theta = 4 \quad \dot{\theta} = 0 \]

\[ r = 2\theta = 2(4) = 8 \]

\[ \dot{r} = 2 \theta = 8 \]

\[ a = \ddot{r} = \dddot{\theta} - \pi(4)^2 = -50.27 \]

\[ a_\theta = r \dddot{\theta} = 2(8)(4) = 64 \]

\[ + \Sigma F_\theta = m a_\theta ; \quad F \cos 57.52^\circ - N \sin 57.52^\circ - 2 = \left(\frac{2}{32.2}\right)(-50.27) \]

\[ - \Sigma F_\theta = m a_\theta ; \quad F \sin 57.52^\circ + N \cos 57.52^\circ = \left(\frac{2}{32.2}\right)(64) \]

Solving:

\[ P = 2.75 \text{ lb} \quad \text{Ans} \]

\[ N_r = 3.08 \text{ lb} \quad \text{Ans} \]

*13-96. The forked rod is used to move the smooth 2-lb particle around the horizontal path in the shape of a limaçon, \( r = (2 + \cos \theta) \) ft. If \( \theta = (0.5t^2) \) rad, where \( t \) is in seconds, determine the force which the rod exerts on the particle at the instant \( t = 1 \) s. The fork and path contact the particle on only one side.

\[ r = 2 - \cos \theta \quad \theta = 0.5t^2 \]

\[ \dot{r} = -\sin \theta \quad \dot{\theta} = 1 \]

\[ \ddot{r} = -\cos \theta \ddot{\theta} - \sin \theta \dot{\theta}^2 \quad \ddot{\theta} = 1 \text{ rad/s}^2 \]

At \( t = 1 \), \( \dot{\theta} = 0.5 \) rad, \( \ddot{\theta} = 1 \) rad/s and \( \ddot{\theta} = 1 \) rad/s^2

\[ r = 2 - \cos 0.5 = 2.8776 \text{ ft} \]

\[ \dot{r} = -\sin 0.5(1) = -0.4794 \text{ ft/s} \]

\[ \ddot{r} = -\cos 0.5(1)^2 - \sin 0.5(1) = -1.357 \text{ ft/s}^2 \]

\[ a_\theta = r \ddot{\theta} + 2 \dot{r} \dot{\theta} = 2.8776(1) + 2(-0.4794)(1) = 1.9187 \text{ ft/s}^2 \]

\[ \omega = \frac{r}{dr/d\theta} = \frac{2 + \cos \theta}{\sin \theta} \bigg|_{\theta = 0.5} = -6.002 \quad \psi = 80.54^\circ \]

\[ \Sigma F_\theta = m a_\theta ; \quad N \cos 90.46^\circ = \frac{2}{32.2}(-1.9187) \quad N = 0.2666 \text{ lb} \]

\[ \Sigma F_\theta = m a_\theta ; \quad F - 0.2666 \sin 90.46^\circ = \frac{2}{32.2}(1.9187) \]

\[ F = 0.162 \text{ lb} \quad \text{Ans} \]
13-99. Determine the normal and frictional driving forces that the partial spiral track exerts on the 200-kg motorcycle at the instant $\theta = \frac{2}{3} \pi$ rad, $\dot{\theta} = 0.4$ rad/s, and $\ddot{\theta} = 0.8$ rad/s$^2$. Neglect the size of the motorcycle.

\[
\theta = \left( \frac{2}{3} \pi \right) = 100^\circ \quad \dot{\theta} = 0.4 \quad \ddot{\theta} = 0.8
\]

\[
r = 5\dot{\theta} = 5 \left( \frac{2}{3} \pi \right) = 26.18
\]

\[
r = 5\ddot{\theta} = 5(0.8) = 4
\]

\[
a = r - r\ddot{\theta}^2 = 4 - 26.18(0.4)^2 = -0.1888
\]

\[
a_2 = r\ddot{\theta} + 2r\dot{\theta} = 26.18(0.8) + 2(2)(0.4) = 22.54
\]

\[
F = \frac{r}{\dot{\theta}} \left( \frac{5(2/3\pi)}{5} \right) = 5.236 \quad \psi = 79.19^\circ
\]

\[
\sum F, = m\dot{\theta}: 
F \sin 10.81^\circ - N \cos 10.81^\circ - 200(9.81)\cos 30^\circ = 200(-0.1888)
\]

\[
\sum \tau, = m\ddot{\theta}: 
F \cos 10.81^\circ - 200(9.81)\sin 30^\circ + N \sin 10.81^\circ = 200(22.54)
\]

\[
F = 5.07 \text{ kN} \quad \text{Ans}
\]

\[
N = 2.74 \text{ kN} \quad \text{Ans}
\]

13-100. Using a forked rod, a smooth cylinder $C$ having a mass of 0.5 kg is forced to move along the vertical slotted path $r = (0.59)$ m, where $\theta$ is in radians. If the angular position of the arm is $\theta = (0.5\pi)$ rad, where $t$ is in seconds, determine the force of the rod on the cylinder and the normal force of the slot on the cylinder at the instant $t = 2$ s. The cylinder is in contact with only one edge of the rod and slot at any instant.

\[
r = 0.59 \quad r = 0.59 \quad \dot{r} = 0.59
\]

\[
\dot{\theta} = 0.5 \pi \quad \ddot{\theta} = 1
\]

\[
N = 2 s
\]

\[
\dot{\theta} = 2 \text{ rad} = 114.59^\circ \quad \dot{\theta} = 2 \text{ rad/s} \quad \ddot{\theta} = 1 \text{ rad/s}^2
\]

\[
r = 1 \text{ m/s} \quad \dot{r} = 0.5 \text{ m/s}^2
\]

\[
\omega \psi = \frac{r}{\dot{\theta}} \left( \frac{0.5(2)}{0.5} \right) = 6.33^\circ
\]

\[
a = r - r\ddot{\theta}^2 = 0.5 - 0(3)^2 = -3.5
\]

\[
a_2 = r\ddot{\theta} + 2r\dot{\theta} = 3(1) + 2(1)(2) = 5
\]

\[
F = \text{mass}\times \text{g}\cos 26.57^\circ - 4.903 \text{cos} 24.59^\circ = 0.5(-3.5)
\]

\[
N = 3.030 \approx 3.03 \text{ N} \quad \text{Ans}
\]

\[
\sum \tau, = m\ddot{\theta}: 
F \sin 26.57^\circ - 4.903 \sin 24.59^\circ = 0.5(1.5)
\]

\[
F = 1.81 \text{ N} \quad \text{Ans}
\]
13-108. The arm is rotating at a rate of \( \dot{\theta} = 5 \text{ rad/s} \) when \( \theta = 2 \text{ rad} / \dot{\theta}^2 \) and \( \dot{\theta} = 90^\circ \). Determine the normal force it must exert on the 0.5-kg particle if the particle is confined to move along the slotted path defined by the horizontal hyperbolic spiral \( r \theta = 0.2 \text{ m} \).

\[
\sigma = \frac{r}{\dot{r}} = 90^\circ
\]

\[
\dot{\theta} = 5 \text{ rad/s}
\]

\[
\ddot{r} = 2 \text{ rad/s}^2
\]

\[
r = 0.2 \dot{\theta} = 0.12732 \text{ m}
\]

\[
\ddot{r} = -0.2 \dot{\theta}^2 \dot{\theta} = -0.40528 \text{ m/s}
\]

\[
\ddot{r} = -0.2 (-2 \dot{\theta}^2 \dot{\theta}^2 + \dot{\theta} \ddot{\theta}) = 2.41801
\]

\[
a_r = \ddot{r} - \frac{r}{r^2} \ddot{\theta} = 2.41801 - 0.12732(5)^2 = -0.7651 \text{ m/s}^2
\]

\[
a_{\theta} = r \ddot{\theta} + 2 \ddot{r} \dot{\theta} = 0.12732(2) + 2(-0.40528)(5) = -3.7982 \text{ m/s}^2
\]

\[
\tan \psi = \frac{\ddot{r}}{\ddot{\theta}} = -0.293
\]

\[
\psi = \tan^{-1} \left( -\frac{9}{2} \right) = -57.5184^\circ
\]

\[\text{Ans:} \quad N_r \cos 52.4816^\circ = 0.5(-0.7651)\]

\[\text{Ans:} \quad F = 0.5(-3.7982)\]

\[\text{Ans:} \quad N_r = -0.463 \text{ N}\]

\[\text{Ans:} \quad F = -1.66 \text{ N}\]

13-109. The collar, which has a weight of 3 lb, slides along the smooth rod lying in the horizontal plane and having the shape of a parabola \( r = 4(1 - \cos \theta) \), where \( \theta \) is in radians and \( r \) is in feet. If the collar's angular rate is constant and equal to \( \dot{\theta} = 4 \text{ rad/s} \), determine the tangential retarding force \( P \) needed to cause the motion and the normal force that the collar exerts on the rod at the instant \( \theta = 90^\circ \).

\[
r = \frac{4}{1 - \cos \theta}
\]

\[
\ddot{r} = \frac{-4 \sin \theta \dot{\theta}}{(1 - \cos \theta)^2}
\]

\[
r = \frac{4}{1 - \cos \theta}
\]

\[
\ddot{r} = \frac{-4 \sin \theta \dot{\theta}}{(1 - \cos \theta)^2}
\]

\[
\ddot{r} = \frac{-4 \sin \theta \dot{\theta}}{(1 - \cos \theta)^2}
\]

\[
\tan \psi = \frac{\ddot{r}}{\ddot{\theta}} = \frac{-4 \sin \theta \dot{\theta}}{4 \dot{\theta}^2} = \frac{1}{4}
\]

\[
\psi = -45^\circ = 135^\circ
\]

\[\text{Ans:} \quad P \sin 45^\circ - N \cos 45^\circ = \frac{3}{32.2}(64)\]

\[\text{Ans:} \quad P \cos 45^\circ - N \sin 45^\circ = \frac{3}{32.2}(-128)\]

Solving,

\[P = 12.6 \text{ lb} \quad \text{Ans}\]

\[N = 4.32 \text{ lb} \quad \text{Ans}\]