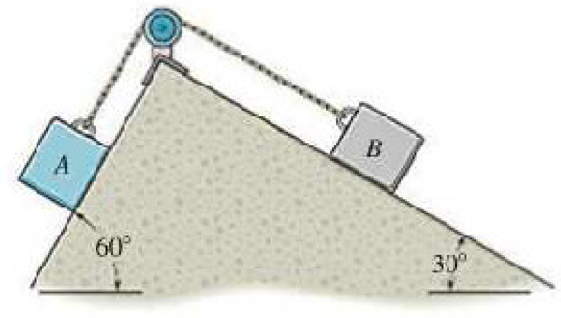
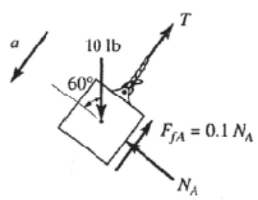
HB,13-17: The double inclined plane supports two blocks A and B, each having a weight of **10** lb. If the coefficient of kinetic friction between the blocks and the plane is $\boldsymbol{\mu_k} = 0.1$, determine the acceleration of each block.



Prob. 13–17

SOLUTION

Equation of Motion: Since blocks A and B are sliding along the plane, the friction forces developed between the blocks and the plane are $(F_f)_A = \mu_k N_A = 0.1\,N_A$ and $(F_f)_B = \mu_k N_B = 0.1 N_B$. Here, $a_A = a_B = a$. Applying Eq. 13–7 to FBD(a), we have

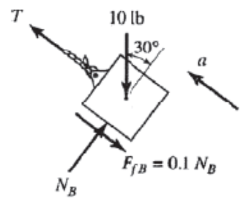


(a)

$$\nwarrow + \sum F_{y'} = ma_{y'}; \quad N_A - 10\cos 60^\circ = \left(\frac{10}{32.2}\right)(0) \quad N_A = 5.00\text{ lb}$$

$$\nearrow + \sum F_{x'} = ma_{x'}; \qquad T + 0.1(5.00) - 10\sin 60^\circ = -\left(\frac{10}{32.2}\right)a \qquad \textbf{(1)}$$

From FBD(b),



(b)

$$\nearrow + \sum F_{y'} = ma_{y'}; \quad N_B - 10\cos 30^\circ = \left(\frac{10}{32.2}\right)(0) \quad N_B = 8.660\text{ lb}$$

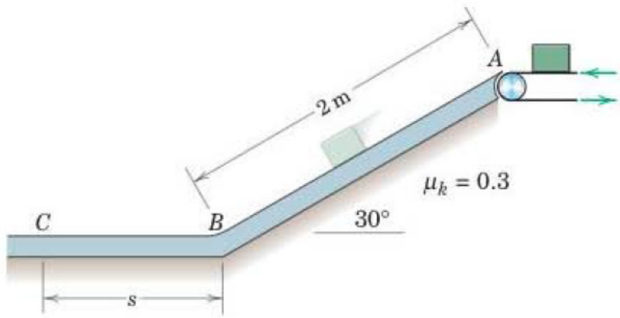
$$\nwarrow + \sum F_{x'} = ma_{x'}; \quad T - 0.1(8.660) - 10\sin 30^\circ = \left(\frac{10}{32.2}\right)a \qquad \textbf{(2)}$$

Solving Eqs. (1) and (2) yields

$$a = 3.69\text{ ft/s}^2 \qquad \textbf{Ans.}$$

$$T = 7.013\text{ lb}$$

Meriam,3/16: A small package is deposited by the conveyor belt onto the 30 degree ramp at **A** with a velocity of ***0.8 m/s***. Calculate the distance ***s*** on the level surface **BC** at which the package comes to rest. The coefficient of kinetic friction for the package and the supporting surface from **A** to **C** is ***0.3***



Problem 3/16

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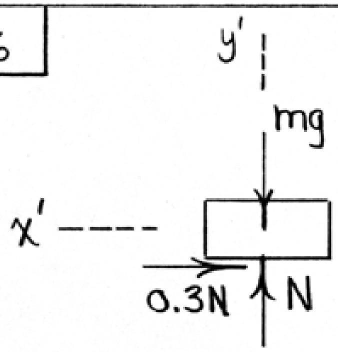
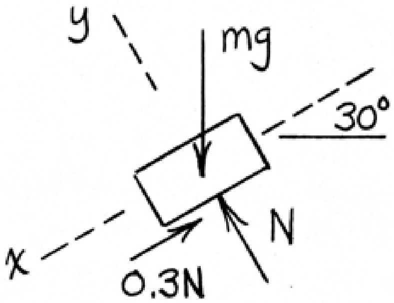




A to B:

$\Sigma F_y = 0 \Rightarrow \quad N = 0.866\, mg$

$\Sigma F_x = m a_x : \quad mg \sin 30° - 0.3(0.866\, mg) = ma$

$a_x = 2.36 \text{ m/s}^2$

$v_B^2 = v_A^2 + 2 a_x d : \quad v_B^2 = 0.8^2 + 2(2.36)(2)$

$v_B = 3.17 \text{ m/s}$

B to C:

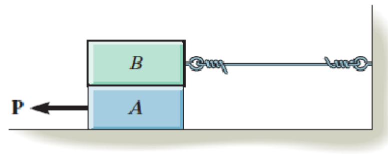
$\Sigma F_{y'} = 0 \Rightarrow \quad N = mg$

$\Sigma F_{x'} = m a_{x'} : \quad -0.3(mg) = m a_{x'}, \quad a_{x'} = -2.94 \text{ m/s}^2$

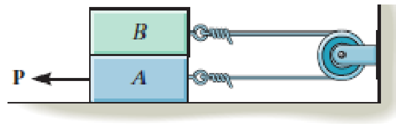
$v_C^2 = v_B^2 + 2 a_{x'} s : \quad 0 = 3.17^2 - 2(2.94)s$

$\underline{s = 1.710 \text{ m}}$

HB,13-34: Each of the two blocks has a mass ***m***. The coefficient of kinetic friction at all surfaces of contact is ***μ***. If a horizontal force ***P*** moves the bottom block, determine the acceleration of the bottom block in cases (a) and (b).



(a)



(b)

SOLUTION

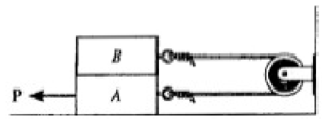
Block A:

(a) $\overset{+}{\leftarrow} \Sigma F_x = ma_x;\qquad P - 3\mu mg = m\,a_A$

$$a_A = \frac{P}{m} - 3\mu g \qquad \textbf{Ans.}$$

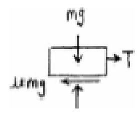
(b) $s_B + s_A = l$

$$a_A = -a_B \qquad (1)$$



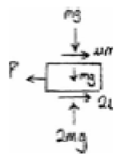
Block A:

$\overset{+}{\leftarrow} \Sigma F_x = ma_x;\qquad P - T - 3\mu mg = m\,a_A \qquad (2)$



Block B:

$\overset{+}{\leftarrow} \Sigma F_x = ma_x;\qquad \mu mg - T = ma_B \qquad (3)$

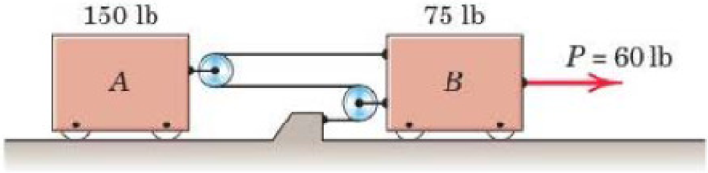


Subtract Eq.(3) from Eq.(2):

$$P - 4\mu mg = m\,(a_A - a_B)$$

Use Eq.(1); $\qquad a_A = \dfrac{P}{2m} - 2\mu g \qquad$ **Ans.**

Meriam,3/38: Determine the accelerations of bodies **A** and **B** and the tension in the cable due to the application of the **60-lb** force. Neglect all friction and the masses of the pulleys.



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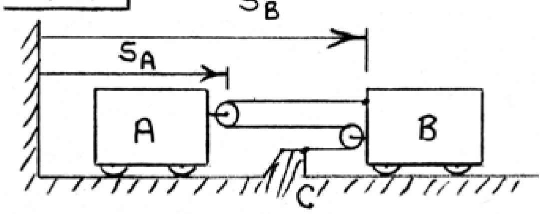
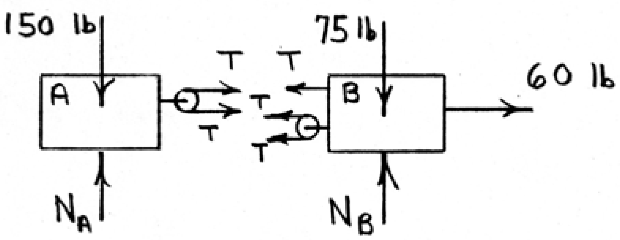


$$L = 2(s_B - s_A) + (s_B - s_C) + \text{constants}$$

$$\Rightarrow \quad 0 = 3a_B - 2a_A \qquad (1)$$



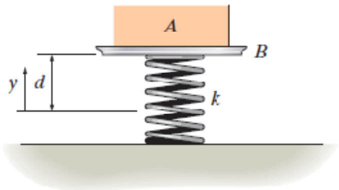
$$\overset{+}{\rightarrow} \Sigma F = ma: \quad (A) \quad 2T = \frac{150}{32.2} a_A \qquad (2)$$

$$(B) \quad 60 - 3T = \frac{75}{32.2} a_B \qquad (3)$$

Solve Eqs. (1)−(3):

$$\begin{cases} a_A = 7.03 \ \text{ft/sec}^2 \\ a_B = 4.68 \ \text{ft/sec}^2 \\ T = 16.36 \ \text{lb} \end{cases}$$

HB,13-51: The block A has a mass $\boldsymbol{m_A}$ and rests on the pan B*,* which has a mass $\boldsymbol{m_B}$. Both are supported by a spring having a stiffness $\boldsymbol{k}$ that is attached to the bottom of the pan and to the ground. Determine the distance $\boldsymbol{d}$ the pan should be pushed down from the equilibrium position and the released from the rest so that separation of the block will take place from the surface of the pan at the instant the spring becomes un-stretched.

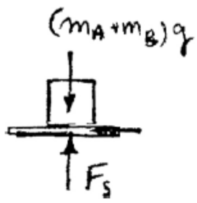


SOLUTION

For Equilibrium

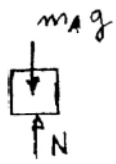
$+\uparrow \Sigma F_y = ma_y; \qquad F_s = (m_A + m_B)g$

$$y_{eq} = \frac{F_s}{k} = \frac{(m_A + m_B)g}{k}$$



Block:

$+\uparrow \Sigma F_y = ma_y; \qquad -m_A g + N = m_A a$



Block and pan

$+\uparrow \Sigma F_y = ma_y; \qquad -(m_A + m_B)g + k(y_{eq} + y) = (m_A + m_B)a$

Thus,

$$-(m_A + m_B)g + k\left[\left(\frac{m_A + m_B}{k}\right)g + y\right] = (m_A + m_B)\left(\frac{-m_A g + N}{m_A}\right)$$

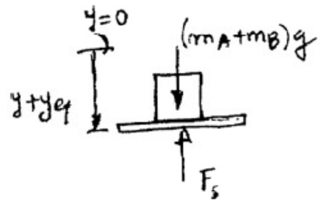
Require $y = d, N = 0$

$$kd = -(m_A + m_B)g$$

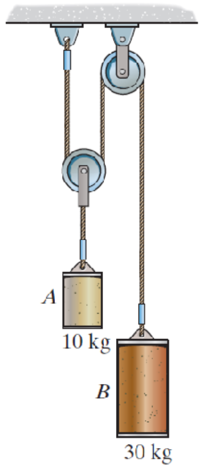
Since d is downward,

$$d = \frac{(m_A + m_B)g}{k}$$

Ans.



HB,13-44: When the blocks are released, determine their acceleration and the tension of the cable. Neglect the mass of the pulley.



SOLUTION

Free-Body Diagram: The free-body diagram of blocks A and B are shown in Figs. b and c, respectively. Here, $\mathbf{a}_A$ and $\mathbf{a}_B$ are assumed to be directed downwards so that they are consistent with the positive sense of position coordinates s_A and s_B of blocks A and B, Fig. a. Since the cable passes over the smooth pulleys, the tension in the cable remains constant throughout.

Equations of Motion: By referring to Figs. b and c,

$$+\uparrow \Sigma F_y = ma_y; \qquad 2T - 10(9.81) = -10a_A \qquad \textbf{(1)}$$

and

$$+\uparrow \Sigma F_y = ma_y; \qquad T - 30(9.81) = -30a_B \qquad \textbf{(2)}$$

Kinematics: We can express the length of the cable in terms of s_A and s_B by referring to Fig. a.

$$2s_A + s_B = l$$

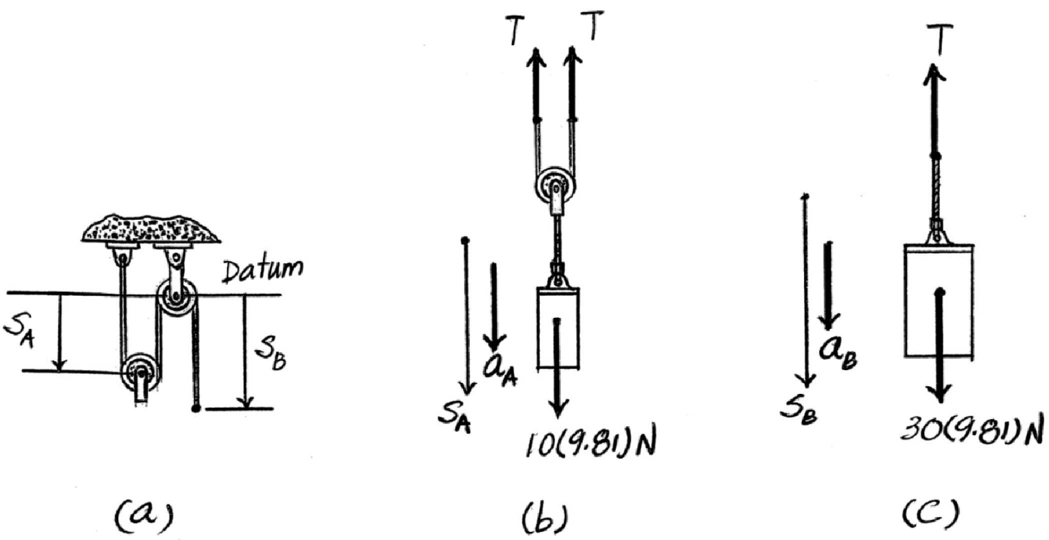
The second derivative of the above equation gives

$$2a_A + a_B = 0 \qquad \textbf{(3)}$$

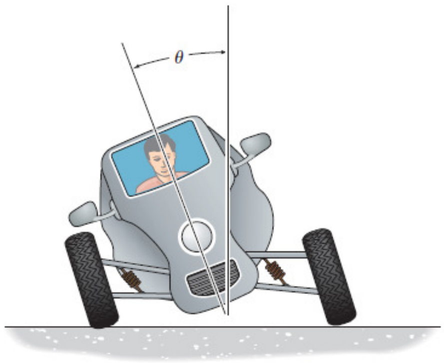
Solving Eqs. (1), (2), and (3) yields

$$a_A = -3.773 \text{ m/s}^2 = 3.77 \text{ m/s}^2 \uparrow \qquad a_B = 7.546 \text{ m/s}^2 = 7.55 \text{ m/s}^2 \downarrow \qquad \textbf{Ans.}$$

$$T = 67.92 \text{ N} = 67.9 \text{ N} \qquad \textbf{Ans.}$$



HB,13-67: The vehicle is designed to combine the feel of a motorcycle with the comfort and safety of an automobile. If the vehicle is traveling at a constant speed of **80 km/hr** along a circular curved road of radius **100 m**, determine the tilt angle ***Θ*** of the vehicle so that only a normal force from the seat acts on the driver. Neglect the size of the driver.



SOLUTION

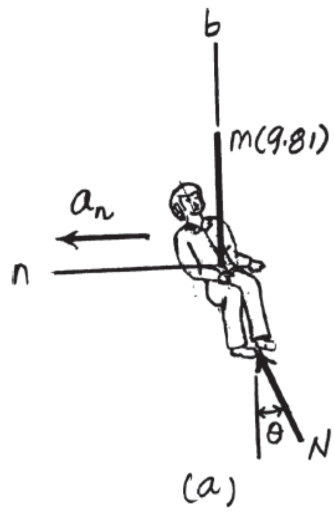
Free-Body Diagram: The free-body diagram of the passenger is shown in Fig. (a). Here, $\mathbf{a}_n$ must be directed towards the center of the circular path (positive n axis).

Equations of Motion: The speed of the passenger is $v = \left(80\,\frac{\text{km}}{\text{h}}\right)\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ h}}{3600\text{ s}}\right) = 22.22$ m/s. Thus, the normal component of the passenger's acceleration is given by $a_n = \frac{v^2}{\rho} = \frac{22.22^2}{100} = 4.938\text{ m/s}^2$. By referring to Fig. (a),

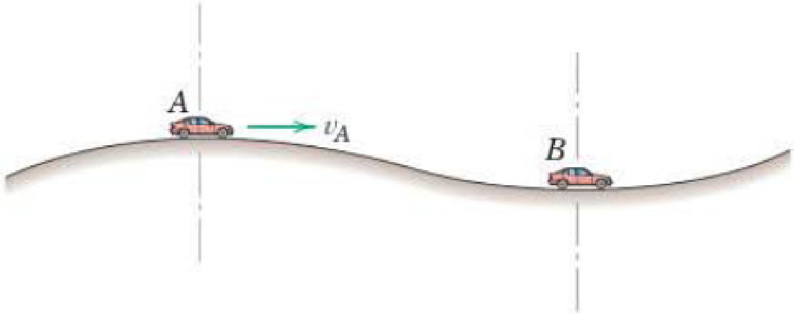
$+\uparrow \Sigma F_b = 0;\qquad N\cos\theta - m(9.81) = 0\qquad N = \frac{9.81m}{\cos\theta}$

$\overset{+}{\leftarrow} \Sigma F_n = ma_n;\qquad \frac{9.81m}{\cos\theta}\sin\theta = m(4.938)$

$\theta = 26.7°$ **Ans.**



Meriam,3/55: The car passes over the top of a vertical curve at **A** with a speed of **60 km/hr** and then passes through the bottom of a dip at **B**. The radii of curvature of the road at **A** and **B** are both **100m**. Find the speed of the car at **B** if the normal force between the road and the tires at **B** is twice that at **A**. The mass center of the car is **1 m** from the road.



Problem 3/55

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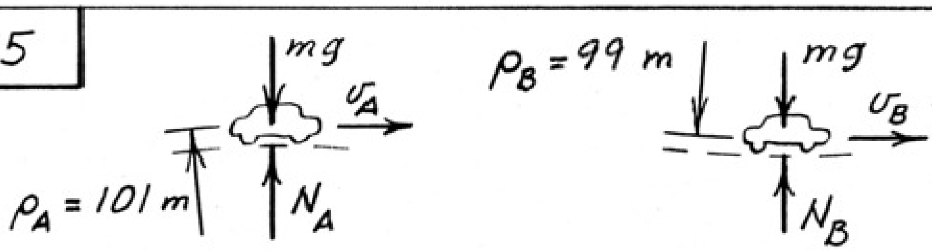


$\Sigma F_n = ma_n$:

$A: \; mg - N_A = m\dfrac{v_A^2}{\rho_A} \qquad B: \; N_B - mg = m\dfrac{v_B^2}{\rho_B}$

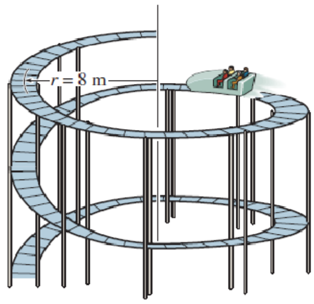
For $N_B = 2N_A$, $\quad m\left(\dfrac{v_B^2}{\rho_B} + g\right) = 2m\left(g - \dfrac{v_A^2}{\rho_A}\right)$

$$v_B^2 = \rho_B g - 2v_A^2\frac{\rho_B}{\rho_A} = 99(9.81) - 2\left(\frac{60 \times 1000}{3600}\right)^2 \frac{99}{101}$$

$$= 427 \ m^2/s^2$$

$v_B = 20.7 \ m/s$ or $\underline{v_B = 74.4 \ km/h}$

HB,13-99: For a short time, the **250-kg** roller coaster car is traveling along the spiral track such that its position measured from the top of the track has components ***r = 8*** *m*, ***Θ = (0.1t + 0.5)*** *rad*, and ***z = (-0.2t)*** *m*, where ***t*** is in seconds. Determine the magnitudes of the components of force which the track exerts on the car in the ***r***, ***Θ***, and ***z*** directions at the instant **t = 2**s. Neglect the size of the car.



SOLUTION

Kinematic: Here, $r = 8\text{ m}$, $\dot{r} = \ddot{r} = 0$. Taking the required time derivatives at $t = 2\text{ s}$, we have

$$\theta = 0.1t + 0.5|_{t=2s} = 0.700\text{ rad} \qquad \dot{\theta} = 0.100\text{ rad/s} \qquad \ddot{\theta} = 0$$

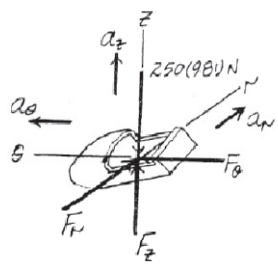
$$z = -0.2t|_{t=2s} = -0.400\text{ m} \qquad \dot{z} = -0.200\text{ m/s} \qquad \ddot{z} = 0$$

Applying Eqs. 12–29, we have

$$a_r = \ddot{r} - r\dot{\theta}^2 = 0 - 8(0.100^2) = -0.0800\text{ m/s}^2$$

$$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta} = 8(0) + 2(0)(0.200) = 0$$

$$a_z = \ddot{z} = 0$$



Equation of Motion:

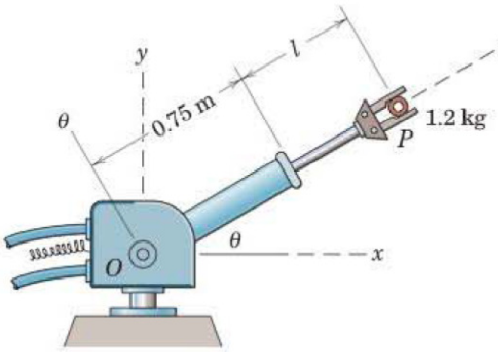
$\Sigma F_r = ma_r;\qquad F_r = 250(-0.0800) = -20.0\text{ N}$ **Ans.**

$\Sigma F_\theta = ma_\theta;\qquad F_\theta = 250(0) = 0$ **Ans.**

$\Sigma F_z = ma_z;\qquad F_z - 250(9.81) = 250(0)$

$F_z = 2452.5\text{ N} = 2.45\text{ kN}$ **Ans.**

Meriam,3/76: The robot arm is elevating and extending simultaneously. At a given instant, $\boldsymbol{\theta} = 30°$, $\dot{\boldsymbol{\theta}} = 40$ *deg/s*, $\ddot{\boldsymbol{\theta}} = 120$ *deg/s*^{2}, $\boldsymbol{l} = 0.5$ *m*, $\dot{\boldsymbol{l}} = 0.4$ *m/s* and $\ddot{\boldsymbol{l}} = -0.3$ *m/s*^{2}. Compute the radial and transverse forces $\boldsymbol{F_r}$ and $\boldsymbol{F_\theta}$ that the arm must exert on the gripped part $\boldsymbol{P}$, which has a mass of *1.2 kg*. Compare with the case of static equilibrium in the same position.



Problem 3/76

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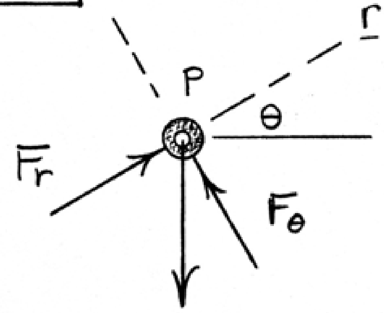

$1.2(9.81) = 11.77$ N

$\theta = 30°$

$\dot{\theta} = 40\left(\frac{\pi}{180}\right) = 0.698$ rad/s

$\ddot{\theta} = 120\left(\frac{\pi}{180}\right) = 2.09$ rad/s^2

$r = 1.25$ m

$\dot{r} = 0.4$ m/s

$\ddot{r} = -0.3$ m/s^2

$\Sigma F_r = ma_r :\quad F_r - 11.77\sin 30° = 1.2\left[-0.3 - 1.25(0.698)^2\right]$

$\underline{F_r = 4.79 \text{ N}}$

$\Sigma F_\theta = ma_\theta :\quad F_\theta - 11.77\cos 30° = 1.2\left[1.25(2.09) + 2(0.4)(0.698)\right]$

$\underline{F_\theta = 14.00 \text{ N}}$

For static case, set $a_\theta = a_r = 0$ & obtain

$\underline{(F_r)_{st} = 5.89 \text{ N}}$, $\underline{(F_\theta)_{st} = 10.19 \text{ N}}$