can spin around the pole as shown in Figure 5-36. Find the tension in the rope when the ball completes 0.5 rev/s and the angle of the ball is 35° with the vertical. SSM

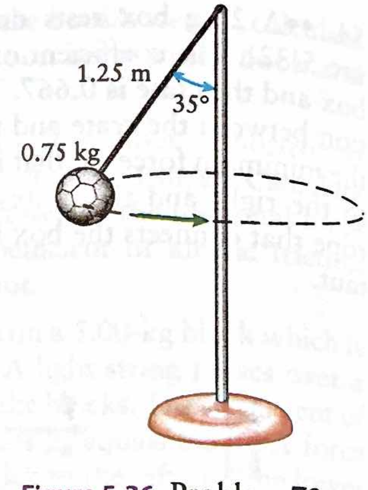


Figure 5-36 Problem 73

74. •The radius of Earth is 6.38×10^6 m and it completes one revolution in 1 day. (a) What is the centripetal acceleration of an object located on the equator? (b) What is the centripetal acceleration of an object located at latitude 40° north?

75. •**Sports** In executing a windmill pitch, a fast-pitch softball player moves her hand through a circular arc of radius 0.31 m. The 0.19-kg ball leaves her hand at 24 m/s. What is the magnitude of the force exerted on the ball by her hand immediately before she releases it?

General Problems

76. •A 150-kg crate rests in the bed of a truck that slows from 50 km/h to a stop in 12 s. The coefficient of static friction between the crate and the truck bed is 0.655. (a) Will the crate slide during the braking period? Explain your answer. (b) What is the minimum stopping time for the truck in order to prevent the crate from sliding?

77. ••The coefficient of static friction between a rubber tire and dry pavement is about 0.80. Assume that a car's engine only turns the two rear wheels and that the weight of the car is uniformly distributed over all four wheels. (a) What limit does the coefficient of static friction place on the time required for a car to accelerate from rest to 60 mph (26.8 m/s)? (b) How can friction accelerate a car *forward* when friction *opposes* motion? SSM

78. ••Two blocks are connected over a massless, frictionless pulley (Figure 5-37). Block m_1 has a mass of 1.0 kg and block m_2 has a mass of 0.4 kg. The angle θ of the incline is 30°. The coefficients of static friction and kinetic friction between block m_1 and the incline are μ_s equal to 0.50 and μ_k equal to 0.40, respectively. What is the value of the tension in the string?

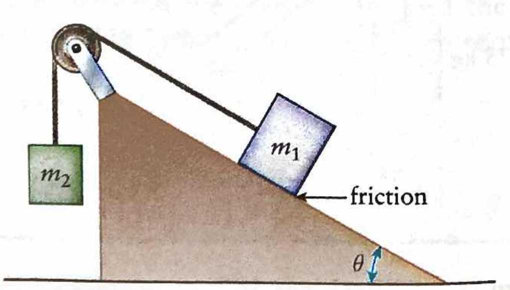


Figure 5-37 Problems 78 and 79

79. ••Two blocks are connected over a massless, frictionless pulley (Figure 5-37). Block m_1 has a mass of 1.0 kg and block m_2 has a mass of 2.0 kg. The angle θ of the incline is 30°. The coefficients of static friction and kinetic friction between block m_1 and the incline are μ_s equal to 0.50 and μ_k equal to 0.40. What is the acceleration of block m_1?

80. •A runaway ski slides down a 250-m-long slope inclined at 37° with the horizontal. If the initial speed is 10 m/s, how long does it take the ski to reach the bottom of the incline if the coefficient of kinetic friction between the ski and snow is (a) 0.10 and (b) 0.15?

81. •In a mail-sorting facility, a 2.5-kg package slides down an inclined plane that makes an angle of 20° with the horizontal. The package has an initial speed of 2 m/s at the top of the incline and it slides a distance of 12.0 m. What must the coefficient of kinetic friction between the package and the inclined plane be so that the package reaches the bottom with no speed? SSM

82. ••In Figure 5-38, two blocks are connected to each other by a massless string over a frictionless pulley. The mass of the block on the left incline is 6.00 kg. Assuming the coefficient of static friction μ_s equals 0.542 for all surfaces, find the range of values of the mass of the block on the right incline so that the system is in equilibrium.

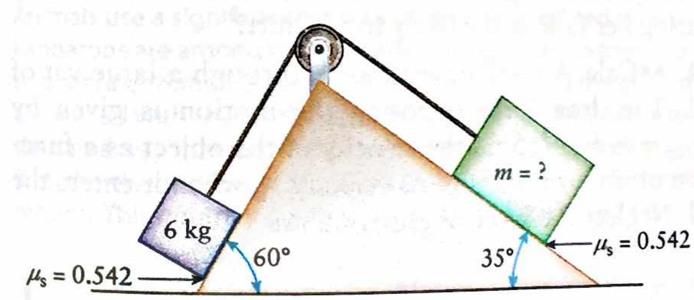


Figure 5-38 Problem 82

83. •••**Calc** With its sails fully deployed, a 100-kg sailboat (including the passenger) is moving at 10 m/s when the mast suddenly snaps and the sail collapses. The boat immediately starts to slow down due to the resistive drag force of the water on the boat. After 5 s, the boat's speed is only 6 m/s. If the drag force of the water is proportional to the speed of the boat, calculate how long it will take before the boat has a speed of 0.5 m/s.

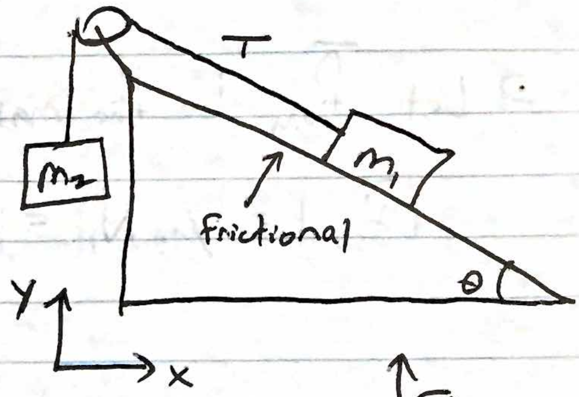
84. ••The terminal velocity of a raindrop that is 4.0 mm in diameter is approximately 8.5 m/s under controlled, windless conditions. The density of water is 1000 kg/m^3. Recall that the density of an object is its mass divided by its volume. (a) If we model the air drag as being proportional to the square of the speed, $F_{drag} = -bv^2$, what is the value of b? (b) Under the same conditions as above, what would be the terminal velocity of a raindrop that is 8.0 mm in diameter? Try to use

$\boxed{\text{K+S \#48}}$ $m_1 = 1.0\,kg$ $\theta = 30°$

$m_2 = 0.4\,kg$ $\mu_s = 0.5$

$\mu_k = 0.4$

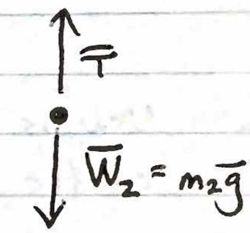
⇝ Looking for T (string tension)



- Not stated if blocks are moving or not (or if they would be after "t=0")
- IF there was no friction on the incline:

$g = -9.8\ m/s^2$

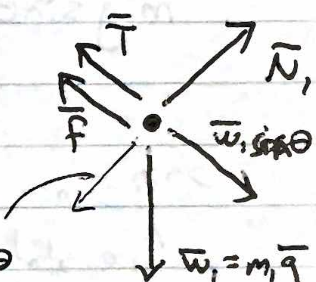
mass 2



$$\Sigma F_2 = \bar{F}_{Net2} = \bar{T} + \bar{W}_2 = \hat{y}\,[T + m_2(-g)]$$

$$⇝ \quad \bar{F}_{Net2} = (T + m_2 g)\hat{y} = m_2 a_2 \hat{y}$$

Mass 1:



$$\Sigma \bar{F}_1 = \bar{T} + \bar{W}_1 \quad ⇝ \text{ break into components}$$

because $a_{1\perp} = 0$

perpendicular to incline ($\perp$): $\Sigma F_{1\perp} = N_1 + W_1\cos\theta = 0$ ⇝ $|N_1| = m_1 g \cos$

$= N_1 + mg\cos\theta$

$= N_1 - 9.8 m_1 \cos\theta \longrightarrow |N_1| = 9.8 m_1 \cos\theta$

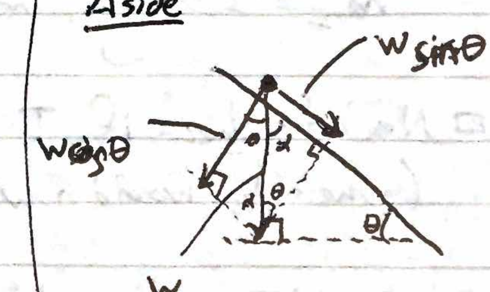
parallel to incline ($\parallel$): $\Sigma F_{1\parallel} = W_1 \sin\theta + T = m_1 a_{1\parallel}$

⇝ Now, $|W_1 \sin\theta| \simeq |(1.0)(-9.8)\sin 30| \simeq 4.9\,N > m_2 g = T = 3.9\,N$

⟹ This tells us that without friction, mass 1 would slide downwards to the right (and mass 2 would move upwards)

- Now, let's bring in friction. What we need to determine is the max. static friction to see if it is sufficient to keep the blocks in place (in which case, we have already determined ~~what~~ we need for T!) (Cont)

Aside



□ Let $\bar{f}_{sm}$ be the max. value for the static friction. Then:

$$|\bar{f}_{sm}| = |\mu_s N_1| = |\mu_s m_1 g \cos\theta| = |(0.5)(1.0)(-9.8)\cos 30|$$
$$\simeq 4.2N$$

Now, is the greater than or equal to the other net forces acting on the block (parallel to the incline)?

$$m_1 g \sin\theta - m_2 g = (9.8)[(1.0)\sin 30 - 0.4)] \simeq 0.98N \simeq 1.0N$$

net grav. force on block "down" incline

⇝ Since $4.2 > 1.0N$, the blocks remain at rest (i.e. static friction is strong enough to keep things from sliding).

⇒ Since things are not moving, the tension in the string is equal to the weight of block 2

$$\Rightarrow \boxed{|\bar{T}| = |m_2 g| \simeq 3.9N}$$

K+S #79

□ Similar set up + diagrams as prior, but now w/ diff. params.
$m_2 = 2.0\,kg$, $m_1 = 1.0\,kg$, $\theta = 30$, $\mu_s = 0.5$, $\mu_k = 0.4$

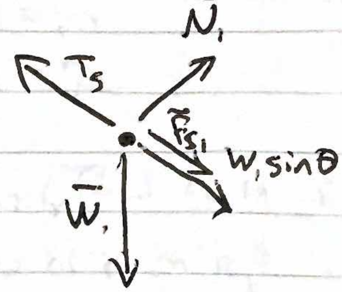
□ Need to check if T_s (due to m_2) is greater than f_s acting on m_1:
(where $\bar{f}_s$ would now presumably act opposite of $\bar{T}_s$)

$$|\bar{T}_s| = |\bar{W}_2| = |m_2 g| = |2.0 \cdot 9.8| = 19.6N$$

(cont)

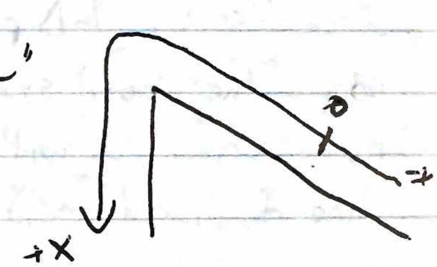
79 (cont)

$$|\bar{f}_{s_1}| = |\mu_s \bar{N}_1| = |(0.5)(1.0)(-9.8)\sin 30| \simeq 4.9\,N$$



→ This tells us that m_2 is heavy enough to overcome the static friction acting on m_1 (because $19.6 > 4.9$ N) and thus m_2 will move downwards while m_1 moves upwards to the left. Further, the rope tension (T) is not T_s and determining T (via consideration of all net force will reveal a_1)

☐ Since this is effectively a 1-D problem, let's create a coord. system (x) so that all "vector" aspects are dealt w/ via a + or − sign



$\bar{W}_2 = m_2 g \hat{x}$ (where $g = 9.8\ m/s^2$)

$\bar{W}_{1\parallel} = -m_1 g \sin\theta\, \hat{x}$

$\bar{f}_{k1} = -\mu_k |\bar{N}_1| \hat{x} = -\mu_k m_1 g \cos\theta$

☐ Ok, so now we can put the pieces together:

net forces on m_2: $\bar{W}_2 - \bar{T} = m_2 a$

" on m_1: $T - m_1 g \sin\theta - \mu_k m_1 g \cos\theta = m_1 a$

both blocks will have the same acceleration

→ Now add both eqns. together to cancel out T (and all are ref. re $\hat{x}$)

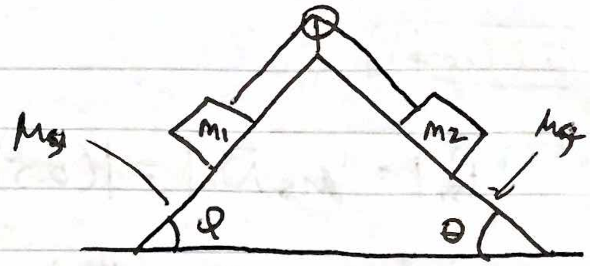
$$a(m_1 + m_2) = W_2 - m_1 g \sin\theta - \mu_k m_1 g \cos\theta$$

$$\Rightarrow a = \frac{m_2 g - m_1 g[\sin\theta + \mu_k \cos\theta]}{m_1 + m_2} = \frac{(2.0)(9.8) - 9.8[\sin 30 + (0.4)\cos 30]}{3}$$

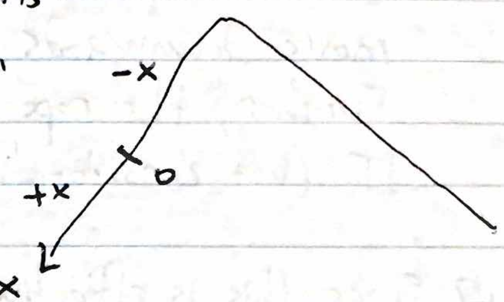
$$\boxed{\simeq 3.8\ m/s^2}$$

K+S 82

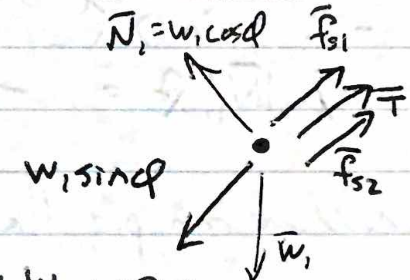
$m_1 = 6.00\,kg$, $\mu_s = 0.542$
$\varphi = 60°$, $\theta = 35°$



- Need to find range of m_2 vals. such that the system is in equilibrium (i.e. all net forces on each block are zero)
- To do this, let's focus on m_1 under two conditions: when m_2 is just about too small such that m_1 slides downwards (call that m_{2L}) and when m_2 is just about too large such that m_1 starts getting pulled upwards ($\equiv m_{2H}$). Further, since this is a 1-D problem like before, we'll adapt the coord system to the right and drop the explicit vector notation (i.e. will just down $\hat{x}$ vector components and the sign takes care of direction)



Mass 1 FBD



$g = 9.8\ m/s^2$

$w_1 = m_1 g$

$w_{2L} = m_{2L} g$

m_{2L} Here, static frictional forces will act along $-\hat{x}$, along w/ the tension (due to the weight of m_{2L})

$$\Sigma F_{m_1} = W_1\sin\varphi - \mu_s W_1\cos\varphi - W_{2L}\sin\theta - \mu_s W_{2L}\cos\theta = 0$$

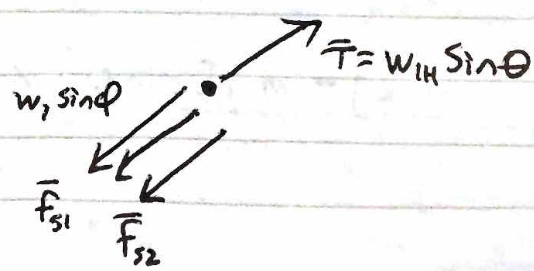
Zero because we are just at the point where the block exp. no net force

$$\rightsquigarrow m_1 g\left[\sin\varphi - \mu_s\cos\varphi\right] = m_{2L} g\left[\sin\theta + \mu_s\cos\theta\right]$$

$$\Rightarrow \boxed{m_{2L} = m_1 \frac{\sin\varphi - \mu_s\cos\varphi}{\sin\theta + \mu_s\cos\theta}}$$

m_{2H} Now since the block (m_1) would move up if $m_2 > m_{2H}$, the frictional forces acts along $+\hat{x}$

Mass 1 FBD



(Cont)

$\boxed{\text{K+S 82 (cont)}}$

$$\Sigma F_{m_1} = W_1 \sin\varphi + \mu_s W_1 \cos\varphi - W_{1H} \sin\theta + \mu_s W_{1H} \cos\theta = 0$$

$$W_{2H} = m_{2H} g \longrightarrow W_1 (\sin\varphi + \mu_s \cos\varphi) = m_{2H} g (\sin\theta - \mu_s \cos\theta)$$

$$\Longrightarrow \boxed{m_{2H} = m_1 \frac{\sin\varphi + \mu_s \cos\varphi}{\sin\theta - \mu_s \cos\theta}}$$

So $m_2 \in [m_{2L}, m_{2H}]$ (i.e. $m_2 = m_{2L}$ through m_{2H}) would represent the mass range over which no movement takes place. We can plug in numerical values at this point

$$m_{2L} = (6.00) \frac{\sin 60 - 0.542 \cdot \cos 60}{\sin 35 + 0.542 \cdot \cos 35} \simeq 3.51 \text{ kg}$$

$$m_{2H} = (6.00) \frac{\sin 60 + 0.542 \cos 60}{\sin 35 - 0.542 \cos 35} \simeq 52.6 \text{ kg}$$

$\Longrightarrow$ Relevant range of m_2 masses here is $\boxed{m_2 \in [3.51, 52.6] \text{ kg}}$