\[ T = mg = 50 \, N \]

\[ m = 5 \, kg \]
7.10

\[ P = 12 \text{ N} \]

\[ m_1 = 1 \text{ kg}, \quad m_2 = 2 \text{ kg}, \quad m_3 = 3 \text{ kg} \]

**Diagram:**

**Force Analysis:**

- \( F_{12} \) due to \( m_2 \)
- \( F_{21} \) due to \( m_1 \)
- \( F_{23} \) due to \( m_3 \)
- \( F_{32} \) due to \( m_2 \)

**Equations:**

1. \( P - F_{12} = m_1 a \)
2. \( F_{21} - F_{23} = m_2 a \)
3. \( F_{32} = m_3 a \)

**Action-Reaction Pairs:**

- \( |\vec{F}_{12}| = |\vec{F}_{21}| \)
- \( |\vec{F}_{23}| = |\vec{F}_{32}| \)

**Solving for \( a \):**

\[ 12 - F_{12} + F_{21} - F_{23} + F_{32} = 6a \]

\[ a = 2 \text{ m/s}^2 \]

**Calculations:**

1. \( F_{32} = 3 \cdot a = 6 \text{ N} \)
2. \( F_{21} - F_{23} = 2a \Rightarrow F_{21} = 2a + F_{23} = 10 \text{ N} \)
\[ \theta_1 = 20^\circ \]

\[ m_1 = 2 \text{ kg} \]

\[ m_2 = 4 \text{ kg} \]

\[ T_1 \sin \theta_1 = m_1 g \quad (\Sigma F_y = 0) \]

\[ T_1 = \frac{2 \cdot 10}{\sin 20^\circ} = 58 \text{ N} \]

\[ T_1 \cos 20^\circ = T_2 \quad (\Sigma F_x = 0) \]

\[ T_2 = 58 \cdot \cos 20^\circ = 55 \text{ N} \]

\[ T_3 \sin \theta_2 = m_2 g \quad (\Sigma F_y = 0) \]

\[ T_3 \cos \theta_2 = T_2 \quad (\Sigma F_x = 0) \]

Divide \( \frac{T_3}{T_2} \) \[ \tan \theta_2 = \frac{m_2 g}{T_2} = \frac{40}{55} \]

\[ \theta_2 = 36^\circ \]

\[ T_3 = \frac{m_2 g}{\sin \theta_2} = \frac{40}{\sin 36^\circ} = 68 \text{ N} \]
What acceleration stops the car in 50 m?

\[ u(t) = u(0) - at \]

\[ u = 0 \text{ at } t = T \]

\[ 0 = 20 \frac{m}{s} - aT, \quad a = \frac{20}{T} \]

\[ s(t) = u(0)t - \frac{1}{2}at^2 \]

\[ s(T) = 50 \text{ m} \]

\[ 50 = 20T - \frac{1}{2} \cdot \frac{20}{T} \cdot T^2 = 20T - 10T \]

\[ T = 5 \text{ s} \]

\[ a = \frac{20}{5} = 4 \frac{m}{s^2} \]

The friction force necessary to decelerate the mug is

\[ f_s = ma = (\frac{1}{2})(4) = 2 \text{ N} \]

The maximum \( f_s = \mu_s N = (0.5)(5) = 2.5 \text{ N} \)

\text{Mug doesn't slide} \quad N = mg
\[ \alpha = 3.0 \, \text{m/s}^2 \]

\[ M_A = M_B = 1 \, \text{kg} \]

\[ m_1 = m_2 = 0.4 \, \text{kg} \]

\[ M = M_A + M_B + m_1 + m_2 = 2.5 \, \text{kg} \]

Free-body diagram for \( M \):

\[ F - Mg = Ma \]

a) \[ F = M(a + g) = 2.5(3 + 10) = 32.5 \, \text{N} \]

b) Tension at top of rope 1:

\[ T_{A,1} = \text{Tension force pulling down on A due to rope 1} \]

\[ T_{A,1} = F - Ma \]

Free-body diagram mass A:

\[ F - Ma = MA \]

\[ T_{A,1} = F - Ma \]

\[ T_{A,1} = 32.5 - 10 - 3 \]

\[ T_{A,1} = 19.5 \, \text{N} \]
4) Free-body diagram rope 1

\[ T_{1,B} = \text{Force B exerts on rope 1} \]

\[ T_{1,A} - T_{1,B} - m_{1}g = m_{1}a \]

\[ T_{1,B} = T_{1,A} - m_{1}(g+a) \]

\[ = 19.5 - \frac{1}{4}(10+3) = 19.5 - 3.25 \]

\[ T_{1,B} = 16.25 \text{ N} \]

a) Free-body diagram MB

\[ T_{B,1} - T_{B,2} - m_{B}g = m_{B}a \]

\[ m_{B}g \]

\[ T_{B,2} = T_{B,1} - m_{B}(g+a) \]

\[ = 16.25 - 13 = 3.25 \text{ N} \]

Check for rope 2

\[ T_{2,B} - m_{2}g = m_{2}a \]

\[ 3.25 - \frac{1}{4} \cdot 10 = \frac{1}{4} \cdot 3 \]

\[ 3.25 - 2.5 = 0.75 = \frac{3}{4} \checkmark \]
\[ m_1 = 4 \text{ kg} \quad m_2 = 3 \text{ kg} \]
\[ \mu_s = 0.6 \text{ between } m_1 \text{ and } m_2 \]
\[ \mu_k = 0.2 \text{ between } m_2 \text{ and floor} \]

What is the maximum force \( F \) that will move \( m_1 \) and \( m_2 \) without \( m_1 \) slipping on \( m_2 \)?

Maximum force gives maximum acceleration which gives minimum time.

Free-body diagram \( m_2 \)

\[ N_1 \text{ is push down on } m_2 \text{ due to } m_1 \]
\[ N_2 \text{ is push up of table} \]

Free-body diagram \( m_1 \)

Action-Reaction pairs \( F_S / F_S \)

\[ F_S \text{ max} = \mu_s N_1 \]
\[ F_k = \mu_k N_2 \]

\[ F_S = \mu_s M_1 g \]

Maximum force

\[ F_k = \mu_k g (m_1 + m_2) \]
horizontal forces

\[ f_s - f_k = m_2 a \]

\[ F - f_s = m_1 a \]

For object \( m_2 \), the acceleration is caused by \( f_s \). The bigger \( f_s \), the bigger the acceleration. The biggest \( f_s \) is \( \mu m g \).

\[ a = \frac{f_{s,\text{max}} - f_k}{m_2} \]

\[ a = \frac{(0.6)(4)(10) - (0.2)(10)(4+3)}{3} = \frac{24 - 14}{3} = \frac{10}{3} \]

Time to go 5m,

\[ s(t) = \frac{1}{2} at^2 = 5 \]

\[ t^2 = \frac{10}{a} = \frac{10}{\frac{10}{3}} = 3 \]

\[ t = \sqrt{3} \]
If $m$ is too small, $M_2$ will pull it up the slope.

If $m$ is "just" big enough, to remain stationary, acceleration $= 0$

Free-body diagram $M_2$:
\[ T, \quad T = M_2 g \]

Free-body diagram $M$:
\[ N = mg \cos \theta \]
\[ f_s \leq \mu_s N \]
\[ f_s + mg \sin \theta = T \]

When $f_s = 0$, $mg \sin \theta = T \rightarrow m = \frac{T}{g \sin \theta}$

When $f_s = \mu_s N = \mu_s mg \cos \theta$, $m = \frac{T}{g (\mu_s \cos \theta + \sin \theta)}$

Smallest $m = \frac{M_2}{M_2 \cos \theta + \sin \theta}$

$M = \frac{M_2}{M_2 \cos \theta + \sin \theta} = \frac{2}{0.8 \cos 20^\circ + \sin 20^\circ} = 1.8 \text{Kg}$
When it starts sliding, $F_k$ replaces $F_s$ and both masses accelerate.

\[ M_2g - T = M_2a \]

\[ T - M_2g \sin \theta - \mu_k M_2g \cos \theta = Ma \]

Add equations so $T'$s cancel.

\[ M_2g - M_2g \sin \theta - \mu_k g \cos \theta = (M + M_2) a \]

\[ a = \frac{M_2 (1 - M \sin \theta - \mu_k M \cos \theta)}{m_2 + m} \]

\[ a = 1.4 \text{ m/s}^2 \]
e) When the block is sliding up the incline, $F_k$ acts down the incline. Use this to find $\alpha$, the deceleration.

Free-body diagram $M_2$:

$$m_2g - T = m_2a$$

Free-body diagram $M_1$:

$$T + F_k + m_1g \sin \theta = m_1a$$

$$m_2g - T = m_2a$$

$$m_2g + m_1g \sin \theta + \mu_k m_1g \cos \theta = (m_1 + m_2)a$$

$$\alpha = \frac{m_2 + m_1 \mu_k \sin \theta + \mu_k m_1 \cos \theta}{m_1 + m_2}$$
\[ a = 6.9 \text{ m/s}^2 \]

Book slides until \( v(t) = 0 \)

\[ v(t) = v(0) - at \]

\[ 0 = 3 - 6.9t \]

\[ t = 0.44 \text{s} \]

\[ s(t) = v(0)t - \frac{1}{2} at^2, \quad t = 0.44 \]

\[ s(0.44) = 0.66 \text{ m} \]

(b) When it stops, is \( m_2 \) big enough to overcome maximum static friction

\[ \text{What size } F_s \text{ keeps the book still?} \]

\[ T + m_g \sin \theta - m_g F_s = 0 \]

\[ m_2 g - T = 0 \]

\[ m_2 g + m_g \sin \theta = F_s = 8.4 \text{ N} \]

\[ F_s, \text{ max} = \mu \cdot m_1 g \cos \theta = 4.7 \text{ N} \]

Not enough, book slides down!
Free-body diagram $M_1$:

$N_1 = M_1 g \cos \theta$

$T_1 + S_1 = M_1 g \sin \theta$

Free-body diagram $M_2$:

$N_2 = M_2 g \cos \theta$

$2T = S_2 + M_2 g \sin \theta$  

$N_2 - T_2 = M_2 g$

$T_1 + T_2 = S_2 + M_2 g \sin \theta$

$T_1 = M_1 g \sin \theta - S_1 = M_1 g \sin \theta - m r N$

$T_1 = M_1 g \sin \theta - m r M_1 g \cos \theta$

$T_1 = (1500)(10) \sin 35^\circ - 0.02(1500)10 \cos 35^\circ$

\[ T_1 = 8358 \text{ N} \]

$T_2 = S_2 + M_2 g \sin \theta - T_1 = 0.02(1500)10 \cos 35^\circ + (1500)10 \cos 35^\circ - 8358$  

$T_2 = 491 \text{ N}$
The painter pulls down on the rope with a force $T$. The reaction force on the rope is upward on the painter. Free-body diagram:

\[ \begin{align*}
T & \uparrow \\
mg & \downarrow \\
\end{align*} \]

\[ T = m \left( g + \frac{a}{2} \right) = \frac{80}{2} \left( 10 + 0.2 \right) \]

\[ T = 40 \left( 10.2 \right) = 408 \text{ N} \]