Problem 1:
A block having a mass of $m = 18.5$ kg is suspended via two cables as shown in the figure. The angles shown in the figure are as follows: $\alpha = 19^\circ$ and $\beta = 34^\circ$.

Randomized Variables

$m = 18.5$ kg
$\alpha = 19^\circ$
$\beta = 34^\circ$

Part (a) From the images below, choose the correct free body diagram.

Schematic Choice:

Part (b) Write an expression for the sum of forces in the x direction in terms of $T_1$, $T_2$, $m$, $\alpha$, and $\beta$. Use the specified coordinate system.

Expression: $\Sigma F_x = \ldots$

Select from the variables below to write your expression. Note that all variables may not be required.
$\cos(\beta)$, $\cos(\phi)$, $\cos(\theta)$, $\sin(\beta)$, $\sin(\phi)$, $\sin(\theta)$, $\alpha$, $0$, $\cos(\alpha)$, $g$, $m$, $\sin(\alpha)$, $t$, $T_1$, $T_2$

Part (c) Write an expression for the sum of forces in the y direction in terms of $T_1$, $T_2$, $m$, $\alpha$, and $\beta$. Use the specified coordinate system.

Expression: $\Sigma F_y = \ldots$

Select from the variables below to write your expression. Note that all variables may not be required.
$\cos(\beta)$, $\cos(\phi)$, $\cos(\theta)$, $\sin(\beta)$, $\sin(\phi)$, $\sin(\theta)$, $\alpha$, $0$, $\cos(\alpha)$, $g$, $m$, $\sin(\alpha)$, $t$, $T_1$, $T_2$

Part (d) Solve for the numeric value of $T_1$, in newtons.

Numeric: A numeric value is expected and not an expression.

$T_1 = \ldots$

Part (e) Solve for the numeric value of $T_2$, in newtons.

Numeric: A numeric value is expected and not an expression.

$T_2 = \ldots$
Problem 2:

\[
\begin{align*}
\text{a) } & \quad T_1 \quad \text{on } A \quad \text{and } \quad T_2 \quad \text{on } B \\
\text{b) } & \quad \sum F_x = T_2 \cos \beta - T_1 \sin \alpha \\
\text{c) } & \quad \sum F_y = T_1 \cos \alpha + T_2 \sin \beta - Mg \\
\text{d) } & \quad \text{Both forces are zero, so start by solving for } T_2 \text{ and eliminating:} \\
& \quad T_2 = T_1 \cos \beta, \quad \sum F_y = T_1 \cos \alpha + T_1 \frac{\sin \alpha}{\cos \beta} \sin \beta - mg = 0 \\
& \quad T_1 \left( \cos \alpha + \sin \alpha \tan \beta \right) = mg, \quad T_1 = \frac{mg}{\cos \alpha + \sin \alpha \tan \beta}, \quad \boxed{T_1 \approx 155.8 \text{ N}} \\
\text{e) } & \quad \text{Use result from (b): } \quad T_2 = T_1 \frac{\sin \alpha}{\cos \beta}, \quad \boxed{T_2 \approx 61.2 \text{ N}}
\end{align*}
\]
A block with a mass of $m = 30 \text{ kg}$ rests on a frictionless surface and is subject to two forces acting on it. The first force is directed in the negative $x$-direction with a magnitude of $F_1 = 10 \text{ N}$. The second has a magnitude of $F_2 = 21 \text{ N}$ and acts on the body at an angle $\theta = 12^\circ$ up from the horizontal as shown.

**Randomized Variables**

$m = 30 \text{ kg}$
$F_1 = 10 \text{ N}$
$F_2 = 21 \text{ N}$
$\theta = 12^\circ$

**Part (a)** Please select the correct free body diagram from the choices below.

**Schematic Choice**

- [Diagram 1]
- [Diagram 2]
- [Diagram 3]
- [Diagram 4]

**Part (b)** Write an expression for the component of net force, $F_{\text{net,x}}$, in the $x$-direction, in terms of the variables given in the problem statement.

**Expression**

$F_{\text{net,x}} = \ldots$

Select from the variables below to write your expression. Note that all variables may not be required.

cos($\alpha$), cos($\phi$), cos($\theta$), sin($\alpha$), sin($\phi$), sin($\theta$), $\alpha$, $\beta$, $\theta$, $d$, $F_1$, $F_2$, $g$, $m$, $t$

**Part (c)** Write an expression for the magnitude of the normal force, $F_N$, acting on the block, in terms of $F_2$ and the other variables of the problem. Assume that the surface it rests on is rigid.

**Expression**

$F_N = \ldots$

Select from the variables below to write your expression. Note that all variables may not be required.

cos($\alpha$), cos($\phi$), cos($\theta$), sin($\alpha$), sin($\phi$), sin($\theta$), $\alpha$, $\beta$, $\theta$, $d$, $F_1$, $F_2$, $g$, $m$, $t$

**Part (d)** Find the block's acceleration in the $x$-direction, $a_x$, in meters per square second.

**Numeric**

$a_x = \ldots$ A numeric value is expected and not an expression.
Problem 3:

a) FBD:

\[ F_N \]

\[ F_g \]

\[ F_\theta \]

\[ F_2 \]

\[ F_1 \]

b) \( \Sigma F_x = F_{2x} + F_1 = F_2 \cos \theta - F_1 \)

\[ F_{net, y} = F_2 \cos \theta - F_1 \]

c) \( \Sigma F_y = F_{3y} + F_N + F_{2y} \rightarrow F_{net, y} = -mg + F_N - F_2 \sin \theta = 0 \)

\[ F_N = F_2 \sin \theta + mg \]

d) \( F_{net, x} = ma_x \rightarrow F_2 \cos \theta - F_1 = ma_x \)

\[ a_x = \frac{F_2 \cos \theta - F_1}{m} \]

\[ a_x \approx 0.35 \text{ m/s}^2 \]
Problem 4

Attached to the rear-view mirror of a car is a small crystal on a string. When the car is stopped at a light, the crystal hangs vertically. When the light turns green, the driver accelerates and notices the crystal makes an angle of $\theta = 14$ degrees with respect to the vertical.

**Randomized Variables**

$\theta = 14$ degrees

**Part (a)** Please select the correct free body diagram, using an inertial coordinate system fixed to the road, given $F_g$ is the force due to gravity, $F_T$ is the tension in the string, $F_a$ is the centrifugal acceleration and $F_N$ is the normal force.

**Schematic Choice:**

![Free Body Diagrams]

**Part (b)** Input an expression for the magnitude of the car’s acceleration in terms of the variables provided - the acceleration due to gravity and $\theta$.

**Expression:**

$a = \frac{mg}{\cos \theta}$

Select from the variables below to write your expression. Note that all variables may not be required.

$\cos (\alpha), \cos (\beta), \cotan (\theta), \sin (\alpha), \sin (\beta), \tan (\theta), \alpha, \beta, \theta, \cos (\theta), \cotan (\theta), d, g, h, j, k, m, P, \sin (\theta), t$

**Part (c)** What is the car’s acceleration in m/s$^2$?

**Numeric:** A numeric value is expected and not an expression.

$a =$

**Part (d)** When the car is no longer accelerating, what is the angle, $\theta$ in degrees?

**Numeric:** A numeric value is expected and not an expression.

$\theta =$

\[ a \approx 2.45 \text{ m/s}^2 \]

b) In the radial direction, $\Sigma F_r = F_T \sin \theta = ma$ (x-direction)

In the vertical direction, $\Sigma F_v = F_T \cos \theta - mg = 0$ (y-direction)

\[ \left( \frac{mg}{\cos \theta} \right) \sin \theta = ma \rightarrow F_T = \frac{mg}{\cos \theta} \]

\[ a = \frac{g \sin \theta}{\cos \theta} \]

\[ a \approx 2.45 \text{ m/s}^2 \]

\[ a \approx 2.45 \text{ m/s}^2 \]

\[ \theta \]

\[ \theta = \tan \theta \]

\[ \Sigma F = 0 \text{ so } FBD \text{ must be } \sqrt{1 - \sin \theta} \]
In the figure, the net external force on the 24-kg mower is stated to be 51 N. If the force of friction opposing the motion is 24 N, what force \( F \) (in newtons) is the person exerting on the mower? Suppose the mower is moving at 1.5 m/s when the force \( F \) is removed. How far will the mower go before stopping?

**Solution**

\[
F_{\text{net}} = F - f \Rightarrow F = F_{\text{net}} + f = 51 \text{ N} + 24 \text{ N} = 75 \text{ N}
\]

\[
F = ma \Rightarrow a = \frac{F}{m} = \frac{-24 \text{ N}}{24 \text{ kg}} = -1.0 \text{ m/s}^2 \text{ so using } v^2 = v_0^2 + 2ax
\]

\[
0 = (1.5 \text{ m/s})^2 + 2(-1.0 \text{ m/s}^2)x \Rightarrow x = 1.125 \text{ m} = 1.1 \text{ m}
\]
Problem 5:

Suppose your car was mired deeply in the mud and you wanted to use the method illustrated in the figure to pull it out. (a) What force would you have to exert perpendicular to the center of the rope to produce a force of 12,000 N on the car if the angle is 2.00°? In this part, explicitly show how you follow the steps in the Problem-Solving Strategy for Newton’s laws of motion. (b) Real ropes stretch under such forces. What force would be exerted on the car if the angle increases to 7.00° and you still apply the force found in part (a) to its center?

Solution (a) Use the figure as the free body diagram.

\[
\begin{align*}
\text{net } F_x &= T \cos \theta - T \cos \theta = 0 \\
\text{net } F_y &= F_\perp - T \sin \theta - T \sin \theta = 0 \\
F_\perp &= 2T \sin \theta = 2(12,000 \text{ N})(\sin 2.00^\circ) = 837.6 \text{ N} = 838 \text{ N}
\end{align*}
\]

(b) \[T = \frac{F_\perp}{2 \sin \theta} = \frac{837.6 \text{ N}}{2 \sin 7.00^\circ} = 3.44 \times 10^3 \text{ N}\]

Problem 6:
Problem 7:

Full solution not currently available at this time.

Cranes use a system of two pulleys to provide mechanical advantage, which reduces the force they need to apply to lift a particular weight (two such possible configurations are shown in the figure). A crane is attempting to lift a compact car with a mass of $m = 701$ kg under the force of gravity.

Randomized Variables

$m = 701$ kg

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Min</th>
<th>Max</th>
<th>Step</th>
<th>Sample Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m$</td>
<td>700</td>
<td>1250</td>
<td>1</td>
<td>701</td>
</tr>
</tbody>
</table>
**Part (a)** The crane's pulley system produces a mechanical advantage of 10. How many times, $x$, does the cable pass over the pulley within the crane? (Assume that the tension in each segment of the rope is the same.)

Correct Algorithm: $x = 5$

<table>
<thead>
<tr>
<th>Choice Info:</th>
<th>Hints:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x = 5$</td>
<td>3 hints available</td>
</tr>
<tr>
<td>$x = 5$</td>
<td>- There are two rope segments for each pass.</td>
</tr>
<tr>
<td>$x = 5$</td>
<td>- Pulleys only change the direction of the tension.</td>
</tr>
<tr>
<td>Buffer + or - 0.15</td>
<td>- Draw a picture - and then a Free Body Diagram of the lower pulley.</td>
</tr>
</tbody>
</table>

**Part (b)** Assuming that the positive y-direction is up, input an expression for the sum of the forces acting on the car in the y-direction, in terms of the force produced by the crane's motor, $F_c$, and the given variables. Assume the motor pulls at a constant velocity.

Correct Equation: $\Sigma F_y = 10 F_c - mg$

<table>
<thead>
<tr>
<th>Choice Info:</th>
<th>Hints:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid Choices: 10, $F_c$, g, m,</td>
<td>3 hints available</td>
</tr>
<tr>
<td>Partial Credit Choices with Feedback:</td>
<td></td>
</tr>
<tr>
<td>Invalid Choices: t, a, 0, d, $\beta$, h, P, i, j, k, a, S</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hints:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Start with a free body diagram.</td>
</tr>
<tr>
<td>- There is 10 times mechanical advantage.</td>
</tr>
<tr>
<td>- There are two forces in the y-direction.</td>
</tr>
</tbody>
</table>

**Part (c)** What is the minimum force, in Newtons, the crane's motor must provide to begin to move the car?

Correct Algorithm: $F_{min} = m*9.81/10$

<table>
<thead>
<tr>
<th>Choice Info:</th>
<th>Hints:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{min} = 701*9.81/10$</td>
<td>2 hints available</td>
</tr>
<tr>
<td>$F_{min} = 701*9.81/10$</td>
<td>- It must overcome the weight at ten times mechanical advantage.</td>
</tr>
<tr>
<td>$F_{min} = 687.681$</td>
<td>- At minimum net force, $a \to 0$.</td>
</tr>
<tr>
<td>Buffer + or - 20.63043</td>
<td></td>
</tr>
</tbody>
</table>

**Part (d)** Assuming the crane's motor is producing a force of $F_c = 1500$ N on the car, what is the car's acceleration, in $m/s^2$?

Correct Algorithm: $a = (10*1500-m*9.81)/m$

<table>
<thead>
<tr>
<th>Choice Info:</th>
<th>Hints:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a = (10<em>1500-701</em>9.81)/701$</td>
<td>3 hints available</td>
</tr>
<tr>
<td>$a = (10<em>1500-701</em>9.81)/701$</td>
<td>- Net force equals mass times acceleration.</td>
</tr>
<tr>
<td>$a = 11.588$</td>
<td>- You know the net force and mass.</td>
</tr>
<tr>
<td>Buffer + or - 0.34764</td>
<td>- Write the second Newton’s law for the car.</td>
</tr>
</tbody>
</table>
Problem 8: A man is attempting to lift a crate using a two part pulley system as shown in the image. The crate has mass $m_3 = 90 \text{ kg}$, and the man has $m_1 = 75 \text{ kg}$. He pulls downward on the rope with a force of magnitude $F = 659 \text{ N}$. 

**Randomized Variables**

$m_2 = 90 \text{ kg}$

$F = 659 \text{ N}$

---

**Part (a)** Using $T$ to describe the magnitude of the tension force, write an expression for the sum of the forces in the y-direction acting on the crate in terms of gravity and the variables provided.

**Expression:**

$\Sigma F_y = \boxed{2T - Mg}$

Select from the variables below to write your expression. Note that all variables may not be required.

$a, \beta, \pi, p, \theta, a, b, c, d, F, g, h, i, j, k, m_1, m_2, P, S, T$

---

**Part (b)** Using the results from above, write an expression for the crate's vertical acceleration, $a_c$, in terms of $T$.

**Expression:**

$a_c = \boxed{\frac{T}{m_2} - g}$

Select from the variables below to write your expression. Note that all variables may not be required.

$a, \beta, \pi, p, \theta, a, b, c, d, F, g, h, i, j, k, m_1, m_2, P, S, T$

---

**Part (c)** What is the magnitude of the tension force, $T$ in newtons?

**Numeric:** A numeric value is expected and not an expression.

$T = \boxed{659}$

---

**Part (d)** What is the block's acceleration, $a_c$, in m/s$^2$?

**Numeric:** A numeric value is expected and not an expression.

$a_c = \boxed{4.83 \text{ m/s}^2}$

---
Problem 9: Two blocks are connected by a massless rope. The rope passes over an ideal (frictionless and massless) pulley such that one block with mass $m_1 = 15$ kg rests horizontally on a table and the other block with mass $m_2 = 10$ kg hangs vertically. Both blocks experience gravity, $g$, and the tension force, $T$.

Randomized Variables

$m_1 = 15$ kg
$m_2 = 10$ kg

Part (a) Assuming friction forces are negligible, write an expression, using only the variables provided, for the acceleration that the block of mass $m_1$ experiences in the x-direction. Your answer should involve the tension, $T$.

Expression:

$a_1 = \frac{T}{m_1}$

Select from the variables below to write your expression. Note that all variables may not be required.

$a$, $b$, $0$, $d$, $g$, $h$, $i$, $j$, $k$, $m$, $m_1$, $m_2$, $P$, $t$, $T$

Part (b) Under the same assumptions, write an expression for the acceleration, $a_2$, the block of mass $m_2$ experiences in the y-direction. Your answer should be in terms of the tension, $T$ and $m_2$.

Expression:

$a_2 = \frac{T - m_2 g}{m_2}$

Select from the variables below to write your expression. Note that all variables may not be required.

$a$, $b$, $0$, $d$, $g$, $h$, $i$, $j$, $k$, $m$, $m_1$, $m_2$, $P$, $t$, $T$

Part (c) Carefully consider how the accelerations $a_1$ and $a_2$ are related. Solve for the magnitude of the acceleration, $a_1$, of the block of mass $m_1$, in meters per square second.

Numeric: A numeric value is expected and not an expression.

$a_1 = \frac{m_2 g}{m_1 + m_2}$

Part (d) Find the magnitude of the tension in the rope, $T$, in newtons.

Numeric: A numeric value is expected and not an expression.

$T = \frac{m_1 g}{1 + \frac{m_2}{m_1}}$

When $a_1 > 0$, $a_2 < 0$, so $a_1 = -a_2$. Then we have $T = m_2 (a_1 + g) = m_2 (g - a_1)$.

Plug into part (a), $a_1 = \frac{m_2}{m_1} (g - a_1) \Rightarrow a_1 (1 + \frac{m_2}{m_1}) = \frac{m_2}{m_1} g$

$a_1 = \frac{\frac{m_1 g}{1 + \frac{m_2}{m_1}}}{m_1 + m_2}$

$a_1 \approx 3.92 \text{ m/s}^2$

$d)$ Use part (a), $T = m_1 a_1$, $T \approx 58.9 \text{ N}$
Problem 10: A block with mass $m_1 = 9.9$ kg rests on the surface of a horizontal table which has a coefficient of kinetic friction of $\mu_k = 0.74$. A second block with a mass $m_2 = 11.9$ kg is connected to the first by an ideal pulley system such that the second block is hanging vertically under the force of gravity. The second block is released and motion occurs.

**Randomized Variables**

- $m_1 = 9.9$ kg
- $m_2 = 11.9$ kg
- $\mu_k = 0.74$

**Part (a)** Using the variable $T$ to represent tension, write an expression for the sum of the forces in the $y$-direction, $\sum F_y$, for block 2.

**Expression**

$\sum F_y = \quad$ ___________________________

Select from the variables below to write your expression. Note that all variables may not be required.

- $a$, $\beta$, $\mu_k$, $\mu_s$, $\pi$, $p$, $\theta$, $a_1$, $a_2$, $d$, $g$, $h$, $i$, $j$, $m$, $m_1$, $m_2$, $P$, $t$, $T$

**Part (b)** Using the variable $T$ to represent tension, write an expression for the sum of the forces in the $x$ direction, $\sum F_x$, for block 1.

**Expression**

$\sum F_x = \quad$ ___________________________

Select from the variables below to write your expression. Note that all variables may not be required.

- $a$, $\beta$, $\mu_k$, $\mu_s$, $\pi$, $p$, $\theta$, $a_1$, $a_2$, $d$, $g$, $h$, $i$, $m_1$, $m_2$, $P$, $T$

**Part (c)** Write an expression for the magnitude of the acceleration of block 2, $a_2$, in terms of the acceleration of block 1, $a_1$. (Assume the cable connecting the masses is ideal.)

**Expression**

$a_2 = \quad$ ___________________________

Select from the variables below to write your expression. Note that all variables may not be required.

- $a$, $\beta$, $\mu_k$, $\mu_s$, $\pi$, $p$, $\theta$, $a_1$, $d$, $g$, $h$, $i$, $m_1$, $m_2$, $P$, $T$

**Part (d)** Write an expression using the variables provided for the magnitude of the tension force, $T$.

**Expression**

$T = \quad$ ___________________________

Select from the variables below to write your expression. Note that all variables may not be required.

- $a$, $\beta$, $\mu_k$, $\mu_s$, $\pi$, $p$, $\theta$, $d$, $g$, $h$, $i$, $m$, $m_1$, $m_2$, $P$, $T$

**Part (e)** What is the tension, $T$ in Newtons?

**Numeric** A numeric value is expected and not an expression.

$T = \quad$ ___________________________
a) \[ \Sigma F_x = T - F_g \]
\[ \Sigma F_y = T - m_2 g \]

b) \[ \Sigma F_x = T - m_1 m_2 g \]

c) \[ |a_1| = |a_2| \] since they are attached

d) If \( a_1 > 0 \) and \( a_2 < 0 \) so \( a_1 = -a_2 \) \( \rightarrow T - m_2 g = m_2 a_2 \) and \( T - m_1 m_2 g = m_1 (-a_2) \) then equal,
\[ \frac{T}{m_2} - g = - \left( \frac{T}{m_1} - m_2 g \right) \rightarrow T \left( \frac{1}{m_1} + \frac{1}{m_2} \right) = m_2 g + g \]
\[ T \left( \frac{m_1 + m_2}{m_1 m_2} \right) = (m_2 + 1) g \]
\[ T = \frac{m_1 m_2 (m_2 + 1)}{m_1 + m_2} g \]

e) \[ T \approx 12.2 \text{ N} \]
Problem 11:

**Integrated Concepts** An elevator filled with passengers has a mass of 1700 kg. 
(a) The elevator accelerates upward from rest at a rate of 1.20 m/s² for 1.50 s. Calculate the tension in the cable supporting the elevator. (b) The elevator continues upward at constant velocity for 8.50 s. What is the tension in the cable during this time? (c) The elevator decelerates at a rate of 0.600 m/s² for 3.00 s. What is the tension in the cable during deceleration? (d) How high has the elevator moved above its original starting point, and what is its final velocity?

Solution

(a) \[ T = m(a + g) = (1700 \text{ kg})(1.20 \text{ m/s²} + 9.80 \text{ m/s²}) = 1.87 \times 10^4 \text{ N} \]

(b) \[ a = 0 \text{ m/s}^2, \text{ so the tension is: } T = mg(1700 \text{ kg})(9.80 \text{ m/s²}) = 1.67 \times 10^4 \text{ N} \]

(c) \[ a = 0.600 \text{ m/s}^2, \text{ but down: } T = m(g - a) = (1700 \text{ kg})(9.80 \text{ m/s²} - 0.600 \text{ m/s²}) = 1.56 \times 10^4 \text{ N} \]

(d)

\[ y_1 = \frac{1}{2}a_{1}t_1^2 = \frac{1}{2}(1.20 \text{ m/s}^2)(1.50 \text{ s})^2 = 1.35 \text{ m and} \]

\[ v_1 = a_{1}t_1 = (1.20 \text{ m/s}^2)(1.50) = 1.80 \text{ m/s} \]

\[ y_2 = v_1t_2 = (1.80 \text{ m/s})(8.50 \text{ s}) = 15.3 \text{ m} \]

\[ y_1 + y_2 + y_3 = 1.35 \text{ m} + 15.3 \text{ m} + 2.70 \text{ m} = 19.35 \text{ m} = 19.4 \text{ m} \text{ and } v_{\text{final}} = 0 \text{ m/s} \]
Problem 12:

**Unreasonable Results** A 75.0-kg man stands on a bathroom scale in an elevator that accelerates from rest to 30.0 m/s in 2.00 s. (a) Calculate the scale reading in newtons and compare it with his weight. (The scale exerts an upward force on him equal to its reading.) (b) What is unreasonable about the result? (c) Which premise is unreasonable, or which premises are inconsistent?

Solution  (a)

![Diagram](image)

Using $a = \frac{v - v_0}{t}$ gives:
Problem 13:

A block is resting on a wooden plank. On one end of the plank is a hinge so the other end may be lifted to create an angle, $\theta$, with respect to the horizontal. The plank has a coefficient of static friction of $\mu_s$.

**Part (a)** Please select the correct Free Body Diagram, where $F_g$ is the force due to gravity, $F_N$ is the normal force, and $F_s$ is the static friction force.

**SchematicChoice** :

![Free Body Diagrams]

**Part (b)** The angle $\theta$ is slowly increased. Write an expression for the angle at which the block begins to move in terms of $\mu_s$.

**Expression** :

$$\theta = \boxed{\ldots}$$

Select from the variables below to write your expression. Note that all variables may not be required.

$\cos(\alpha), \cos(\beta), \cos(\gamma), \sin(\alpha), \sin(\beta), \sin(\gamma), \mu_s, \theta, 0, d, g, m, t$

**Part (c)** If a student measures that the block begins to move at an angle of $\theta = 42^\circ$, what is the numerical value of the coefficient of static friction, $\mu_s$?

**Numeric** : A numeric value is expected and not an expression.

$$\mu_s = \boxed{\ldots}$$
Problem 14:

a) \[ F_N \]

\[ \begin{align*}
\Sigma F_x & = F_s - F_g = 0 \rightarrow F_s = F_g \leq \mu_s F_N. \\
\Sigma F_y & = F_N - F_g = F_N - mg \cos \theta = 0, \quad F_N = mg \cos \theta \\
F_g & \leq \mu_s F_N \rightarrow mg \sin \theta \leq \mu_s mg \cos \theta \rightarrow \tan \theta \leq \mu_s. \quad \text{No equality occurs at maximum, so} \quad \theta = \arctan(\mu_s)
\end{align*} \]

b) Take a coordinate system along the ramp. Then

\[ \begin{align*}
\Sigma F_x & = F_s - F_g = 0 \\
\Sigma F_y & = F_N - F_g = F_N - mg \cos \theta = 0, \quad F_N = mg \cos \theta \\
F_g & \leq \mu_s F_N \rightarrow mg \sin \theta \leq \mu_s mg \cos \theta \rightarrow \tan \theta \leq \mu_s. \quad \text{No equality occurs at maximum, so} \quad \theta = \arctan(\mu_s)
\end{align*} \]

c) \[ \mu_s = \tan \theta \quad \text{so} \quad \mu_s = 0.90 \]
A woman holds a book by placing it between her hands such that she presses at right angles to the front and back covers. The book has a mass of \( m = 1.1 \text{ kg} \) and the coefficient of static friction between her hand and the book is \( \mu_s = 0.58 \).

**Problem 15**:

**Randomized Variables**

\[
\begin{align*}
m &= 1.1 \text{ kg} \\
\mu_s &= 0.58
\end{align*}
\]

**Part (a)** What is the weight of the book, \( F_{gb} \) in Newtons?

**Numeric**: A numeric value is expected and not an expression.

\[
F_{gb} = \text{[value] N}
\]

**Part (b)** What is the minimum force she must apply with each of her hands, \( F_{min} \) in Newtons, to keep the book from falling?

**Numeric**: A numeric value is expected and not an expression.

\[
F_{min} = \frac{mg}{2\mu}
\]

\[
F_{min} \approx 9.3 \text{ N}
\]
A book with mass \( m = 2.5 \) kg rests on the surface of a table. The coefficient of static friction between the book and the table is \( \mu_s = 0.68 \) and the coefficient of kinetic friction is \( \mu_k = 0.32 \).

**Randomized Variables**

\[
\begin{align*}
m & = \text{2.5 kg} \\
\mu_s & = \text{0.68} \\
\mu_k & = \text{0.32}
\end{align*}
\]

**Part (a)** Write an expression for \( F_m \) the minimum force required to produce movement of the book on the surface.

**Expression**:

\[
F_m = \Box
\]

Select from the variables below to write your expression. Note that all variables may not be required.

\( a, \, \beta, \, \mu_k, \, \mu_s, \, \pi, \, 0, \, d, \, g, \, i, \, j, \, k, \, m, \, P, \, t \)

**Part (b)** Solve numerically for the magnitude of the force \( F_m \) in Newtons.

**Numeric** : A numeric value is expected and not an expression.

\[
F_m = \Box
\]

**Part (c)** Write an expression for \( a \), the book's acceleration, after it begins moving. (Assume the minimum force, \( F_m \), continues to be applied.)

**Expression**:

\[
a = \Box
\]

Select from the variables below to write your expression. Note that all variables may not be required.

\( a, \, \beta, \, \mu_k, \, \mu_s, \, \pi, \, 0, \, d, \, g, \, i, \, j, \, k, \, m, \, P, \, t \)

**Part (d)** Solve numerically for the acceleration, \( a \) in m/s².

**Numeric** : A numeric value is expected and not an expression.

\[
a = \Box
\]

a) Newton's 2nd law, \( \Sigma F = F_m - F_s = 0 \), \( F_m = F_s = \mu_s mg \)

\[ F_m = \mu_s mg \]

b) \( F_m \approx 14.7 \) N

c) \( \Sigma F = F_m - F_k = ma \rightarrow a = \frac{1}{m} (F_m - \mu_k mg) = \frac{1}{m} (\mu_s mg - \mu_k mg) \)

\[ a = (\mu_s - \mu_k)g \]

d) \( a \approx 3.58 \) m/s²