1. A block of mass \( m \), acted on by a force \( F \) directed horizontally, slides up an inclined plane that makes an angle \( \theta \) with the horizontal. The coefficient of sliding friction between the block and the plane is \( \mu \).
   
a. On the diagram of the block below, draw and label all the forces that act on the block as it slides up the plane.

   ![Diagram of block sliding up an inclined plane](image)

   b. Develop an expression in terms of \( m \), \( \theta \), \( \mu \), \( F \), and \( g \) for the block's acceleration up the incline.
   
c. Develop an expression for the magnitude of the force \( F \) that will allow the block to slide up the plane with a constant velocity. What relation must \( \theta \) and \( \mu \) satisfy in order for the solution to be physically meaningful?

2. A.
B. \( F_{\text{NET}} = m \cdot a = F_{\text{up}} - F_{\text{down}} = F \cdot \cos \theta - F_t - F_x \)

\[
m \cdot a = F \cdot \cos \theta - \mu F_N - F_w \sin \theta
\]

\[
m \cdot a = F \cdot \cos \theta - \mu F_y - m \cdot g \sin \theta
\]

\[
m \cdot a = F \cdot \cos \theta - \mu \cdot (m \cdot g \cos \theta + F \cdot \sin \theta) - m \cdot g \sin \theta
\]

\[
m \cdot a = F \cdot \cos \theta - \mu \cdot m \cdot g \cos \theta - \mu \cdot F \cdot \sin \theta - m \cdot g \sin \theta
\]

\[
m \cdot a = F \cdot \cos \theta - \mu \cdot F \cdot \sin \theta - \mu \cdot m \cdot g \cos \theta - m \cdot g \sin \theta
\]

\[
a = \frac{F \cdot (\cos \theta - u \cdot \sin \theta) - m \cdot g \cdot (u \cdot \cos \theta + \sin \theta)}{m}
\]

C. \( F_{\text{NET}} = m \cdot a = 0 = F_{\text{up}} - F_{\text{down}} = F_x - F_t - m \cdot g \sin \theta \)

\[
0 = F_x - F_t - m \cdot g \sin \theta
\]

\[
F_t + m \cdot g \sin \theta = F_x
\]

\[
\mu F_N + m \cdot g \sin \theta = F \cdot \cos \theta
\]

\[
\mu F_y + m \cdot g \sin \theta = F \cdot \cos \theta
\]

\[
\mu \cdot (m \cdot g \cos \theta + F \cdot \sin \theta) + m \cdot g \sin \theta = F \cdot \cos \theta
\]

\[
\mu \cdot m \cdot g \cos \theta + \mu \cdot F \cdot \sin \theta + m \cdot g \sin \theta = F \cdot \cos \theta
\]

\[
\frac{\mu \cdot m \cdot g \cos \theta + \mu \cdot F \cdot \sin \theta + m \cdot g \sin \theta}{\cos \theta} = F
\]
2. A horizontal force $F$ is applied to a small block of mass $m_1$ to make it slide along the top of a larger block of mass $m_2$ and length $L$. The coefficient of kinetic friction between the blocks is $\mu$. The larger block slides without friction along a horizontal surface. The blocks start from rest with the smaller block at one end of the larger block.

a. On the diagram below draw and label all the forces acting on each block.

b. Find the acceleration of each block: $a_1$ and $a_2$, relative to the horizontal surface.

c. In terms of $L$, $a_1$, and $a_2$ find the time $t$ needed for the small block to slide off the end of the larger block.

d. Find the expression for the energy dissipated as heat because of the friction between the blocks.

3. A. The formula for uniformly accelerated motion is $x = \frac{1}{2}a t^2$

B. Normally, solving for $t$, you get $t = \frac{\sqrt{2x}}{a}$ if the block were moving with an acceleration $a$, but in this case, it is the difference between the accelerations of the two blocks:

$$t = \frac{\sqrt{2L}}{a_1 - a_2}$$

Substituting $L$ for $x$, we get $t = \frac{\sqrt{2L}}{a_1 - a_2}$

D. $W = F \times d = F_1 \times d = \mu \cdot F_N \times d = \mu \cdot F_W \times d = \mu \cdot mg \times L$
3. A 500 kg box rests on a platform of the electrical fork-lift. Starting from rest at time $t = 0$, the box is lowered with a downward acceleration of $1.4 \text{ m/s}^2$.

a. Determine the upward force exerted by the horizontal platform on the box as it is lowered.

At time $t = 0$, the fork-lift also begins to move forward with an acceleration of $1.9 \text{ m/s}^2$ while lowering the box. The box doesn’t slip or tip over.

$$F_{\text{NET}} = m \cdot a = F_w - F_N \rightarrow 500 \text{ kg} \cdot 1.4 \text{ m/s}^2 = m \cdot g - F_N \rightarrow 700 \text{ N} = 500 \text{ kg} \cdot 10 \text{ m/s}^2 - F_N \rightarrow 700 = F_N - 5000 \rightarrow 4300 \text{ N} = F_N$$

b. Determine the friction force on the box.

If the box doesn’t slip then the amount of friction ($F_f$) between the box and the forklift platform must be just enough to counteract the forward force acting on the box.

$$F_f = m \cdot a = 500 \text{ kg} \cdot 1.9 \text{ m/s}^2 = 950 \text{ N}$$

c. If the box doesn’t slip, determine the minimum coefficient of static friction between the box and the platform.

$$F_f = \mu \cdot F_N \rightarrow 950 \text{ N} = \mu \cdot 950 = \mu \cdot m \cdot g \rightarrow 950 = \mu \cdot 500 \text{ kg} \cdot 10 \text{ m/s}^2 \rightarrow 0.19 = \mu$$

Determine the expression that describes the path of the box ($y$ as a function of $x$), assuming, at time $t = 0$ the box has a horizontal position $x_0 = 0$ and a vertical position $y = 2.5 \text{ m}$ above the ground, with zero velocity.

Distance is given by $x = x_0 + v_{x_0} \cdot t + \frac{1}{2} \cdot a \cdot t^2$. The two motions – horizontal and vertical - are independent of each other so we can find the separate displacements.

$$x = x_0 + v_{x_0} \cdot t + \frac{1}{2} \cdot a \cdot t^2 = 0 + 0 + \frac{1}{2} \cdot 1.9 \cdot t^2 \rightarrow x = 0.95 \cdot t^2$$

$$y = y_0 + v_{y_0} \cdot t + \frac{1}{2} \cdot a \cdot t^2 = 2.5 + 0 - \frac{1}{2} \cdot 1.4 \cdot t^2 \rightarrow y = 2.5 - 0.7 \cdot t^2$$

So now we have $x$ as a function of $t$ and $y$ as a function of $t$. Now if we want to find $y$ as a function of $x$, we need to solve the first formula (the one that has an $x$) for $t$, and then substitute it into the second formula that has a $y$. This way we get rid of the $t$’s.

$$x = 0.95 \cdot t^2 \rightarrow t = \sqrt{\frac{x}{0.95}}$$
Substituting into the $y$-equation → $y = 2.5 - 0.7t^2 = 2.5 - 0.7 \left( \frac{x}{0.95} \right)^2 = 2.5 - 0.7 \left( \frac{x}{0.95} \right)$

\[ y = 2.5 - 0.74x \]

d. On the coordinate system below sketch the path taken by the box.

E. The shape is a curve and not a straight line because acceleration is happening. The shape is a downwards opening parabolic shape because the descent ($-1.4 \text{ m/s}^2$) is slower than the forward motion ($1.9 \text{ m/s}^2$). If the accelerations had been inverted, the graph could have looked more like...