1. In the figure, the box has mass \( m = 12 \) kg, the pushing force \( P = 58 \) N, and the angle \( \theta = 27^\circ \). Answer the following two questions.

   a. Draw the "free body diagram." This should show the "forces and nothing but the forces" acting on the mass \( m \). There is a frictional force, whose magnitude can be called \( f \), acting between the mass and the rigid floor.

   \[
   \begin{align*}
   \vec{F}_{\text{friction}} &= f \cos \theta - P \\
   \vec{F}_{\text{normal}} &= N - P \sin \theta
   \end{align*}
   \]

   \[
   f = \mu N = \mu (12 \text{ kg})(9.8 \text{ m/s}^2) \sin 27^\circ = 144 \text{ N}
   \]

   b. If there is no friction \( (f=0) \), what is the acceleration \( a \) (magnitude and direction)?

   \[
   m a_x = F_{\text{net},x} = P \cos \theta = 58 \text{ N} \cos 27^\circ = 51.7 \text{ N}
   \]

   \[
   a_x = \frac{51.7 \text{ N}}{12 \text{ kg}} = 4.3 \text{ m/s}^2 \quad \text{to the right}
   \]

   c. What is the "normal force" (magnitude and direction)?

   \[
   F_{\text{net},y} = 0 = N - mg - P \sin \theta 
   \]

   \[
   N = mg \cos \theta = (12 \text{ kg})(9.8 \text{ m/s}^2) \cos 27^\circ = 105 \text{ N}
   \]

   d. If the coefficient of kinetic friction is \( \mu = 0.20 \), what is the acceleration?

   \[
   m a_x = F_{\text{net},x} = P \cos \theta - \mu N = 51.7 \text{ N} - (0.20)(144 \text{ N}) = 22.9 \text{ N}
   \]

   \[
   a_x = \frac{22.9 \text{ N}}{12 \text{ kg}} = 1.9 \text{ m/s}^2 \quad \text{to the right}
   \]

2. A box of mass \( m=12\) kg is sliding downward on a rough surface inclined by \( \theta = 27^\circ \) to the horizontal.

   a. Draw the free body diagram (note – you do not know yet whether the acceleration is positive, negative, or zero. That's OK because acceleration "does not belong" on the free body diagram.)

   \[
   \begin{align*}
   \vec{F}_{\text{friction}} &= \mu N \cos \theta - \mu mg \sin 27^\circ \\
   \vec{F}_{\text{normal}} &= N - mg \cos \theta
   \end{align*}
   \]

   b. What is the normal force (magnitude and direction)? Since \( a_1 = 0 \), \( F_{\text{net}} = 0 \)

   \[
   0 = N - mg \cos \theta \implies N = mg \cos \theta = (12 \text{ kg})(9.8 \text{ m/s}^2) \cos 27^\circ = 105 \text{ N}
   \]

   c. Suppose the coefficient of kinetic friction is \( \mu = 0.20 \). What is the acceleration (magnitude and direction)?

   \[
   \begin{align*}
   ma_1 &= \frac{mg \sin \theta - \mu mg \cos \theta}{m} \\
   a_1 &= (9.8 \text{ m/s}^2)(0.20)\cos 27^\circ = 2.7 \text{ m/s}^2 \quad \text{down the slope}
   \end{align*}
   \]

   d. Suppose the coefficient of kinetic friction is \( \mu = 0.60 \). What is the acceleration (magnitude and direction)?

   \[
   \begin{align*}
   a_2 &= (9.8 \text{ m/s}^2)(0.60)\cos 27^\circ = 4.3 \text{ m/s}^2 \quad \text{up the slope}
   \end{align*}
   \]

   e. If the initial velocity is \( 2.5 \text{ m/s} \) down the plane, how long does the motion last (in case d)?

   \[
   v_f = 0 = v_i + at \\
   0 = 2.5 \text{ m/s} - (0.79 \text{ m/s}^2) \cdot t = 0 \\
   t = \frac{2.5 \text{ m/s}}{0.79 \text{ m/s}^2} = 3.2 \text{ s}
   \]

   f. How far does the mass go (in case e)?

   \[
   \begin{align*}
   d &= \frac{v_i + v_f}{2} \cdot t \\
   &= \frac{2.5 \text{ m/s}}{2} \cdot 3.2 \text{ s} = 4.0 \text{ m}
   \end{align*}
   \]

   * Note Even though ("magnitude + direction") is not