A 10 kg block of steel is at rest on a horizontal table. The coefficient of static friction between block and table is 0.50.

(a) What is the magnitude of the horizontal force that will just start the block moving?
(b) What is the magnitude of a force acting upward 60° from the horizontal that will just start the block moving?
(c) If the force acts down at 60° from the horizontal, how large can it be without causing the block to move?

\[ a = \begin{align*}
\vec{F} & \quad \vec{F}_N \quad \vec{F} \\
\text{Since there is no vertical acceleration,} & \\
N - m/g & = 0 \\
N & = m/g \\
\text{The block will not move until } F & \text{ exceeds the maximum possible frictional force, namely } \mu_s N. \\
\text{The minimum } F & \text{ is thus } \\
F_{\text{min}} & = \mu_s N = \mu_s \frac{m}{g} = (0.50)(10\,\text{kg})(9.80 \,\text{m/s}^2) \\
\text{Thus } F_{\text{min}} & = 49 \,\text{N} \\
\end{align*} \]

\[ b = \begin{align*}
\vec{F} & \quad \vec{F}_N \quad \vec{F} \\
\text{Now the net vertical force is} & \\
N + F \sin \theta - m/g & = 0 \\
N & = m/g - F \sin \theta \\
\text{The limiting value of } F & \text{ is given by} \\
F \cos \theta - F & = 0 \quad (\text{horizontal net force}) \\
F \cos \theta & = \mu_s (m/g - F \sin \theta) \\
F & = \frac{\mu_s m/g}{\cos \theta + \mu_s \sin \theta} = \frac{(0.50)(10\,\text{kg})(9.80 \,\text{m/s}^2)}{(0.50) + (0.50)(0.866)} \\
\text{Thus } F & = 53 \,\text{N} \\
\end{align*} \]

\[ c = \begin{align*}
\vec{F} & \quad \vec{F}_N \quad \vec{F} \\
\text{This time } N & = m/g + F \sin \theta \\
F & = \frac{\mu_s m/g}{\cos \theta - \mu_s \sin \theta} = \frac{(0.50)(10\,\text{kg})(9.80 \,\text{m/s}^2)}{(0.50) - (0.50)(0.866)} \\
\text{Thus } F & = 7.3 \times 10^2 \,\text{N} \\
\end{align*} \]