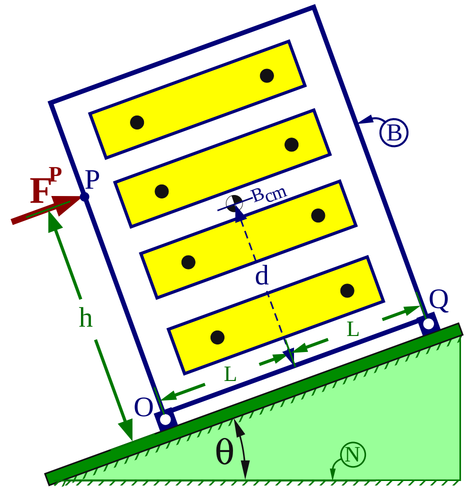
16.9 FE/EIT Review – Bureau sliding up inclined plane (constant speed, 2D analysis, kinetic friction).

A rigid uniform-density bureau B is in contact with an inclined plane at points O and Q of B.
A person applies a force of magnitude F^P at point P of B (the force is directed up the inclined plane).

Description	Symbol	Value
Angle between inclined plane and local horizontal	θ	30°
Mass of bureau	m	10 kg
Earth's gravitational acceleration	g	10 m/s^2
Half-width of bureau	L	0.2 m
Distance between points O and P	h	0.5 m
Distance between B_{cm} and line $\overline{OQ}$	d	0.3 m
Coefficient of static friction between B and plane	μ_s	
Coefficient of kinetic friction between B and plane	μ_k	
Measure of force on B from person	F^P	**TBD**
Measure of normal force on O from inclined plane	F_y^O	**TBD**
Downhill measure of friction force on O	F_x^O	**TBD**
Measure of normal force on Q from inclined plane	F_y^Q	**TBD**
Downhill measure of friction force on Q	F_x^Q	**TBD**



Form a matrix equation governing F^P, F_y^O, F_y^Q when B slides uphill at **constant speed**.
Next, using $\mu_k = 0$, solve the equations for F^P, F_y^O, F_y^Q.
Result: (in terms of θ, m, g, L, h, d, μ_k – **use static equilibrium**).

$$\begin{bmatrix} 1 & -\mu_k & -\mu_k \\ 0 & 1 & 1 \\ -h & 0 & 2L \end{bmatrix} \begin{bmatrix} F^P \\ F_y^O \\ F_y^Q \end{bmatrix} = \begin{bmatrix} m\,g\,\sin(\theta) \\ m\,g\,\cos(\theta) \\ m\,g\,[L\cos(\theta) - d\sin(\theta)] \end{bmatrix} \Rightarrow \begin{array}{l} F^P = m\,g\,\sin(\theta) \\ F_y^O = 0.5\,m\,g\,[\cos(\theta) - \frac{h-d}{L}\sin(\theta)] \\ F_y^Q = 0.5\,m\,g\,[\cos(\theta) + \frac{h-d}{L}\sin(\theta)] \end{array}$$

Optional: Verify that when $\mu_k = 0.2$, $F^P \approx 67.32$, $F_y^O \approx 89.95$, $F_y^Q \approx$ -3.35.

Solution at www.MotionGenesis.com ⇒ Get Started ⇒ Simple statics.