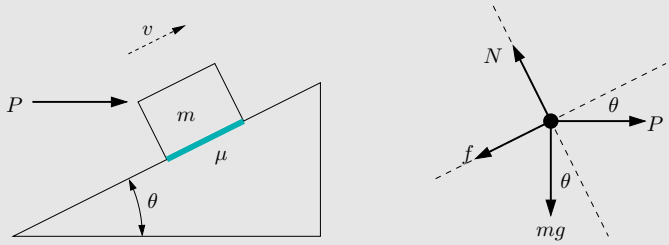
H–37 You have been asked to supply a surface coating for a ramp. Boxes with mass m will be pushed up the ramp, which has an angle measured from the horizontal of θ. The boxes will be pushed by a mechanical arm supplying a constant **horizontal** force P. The boxes must move up the incline at a constant speed. Your goal is to determine the coefficient of kinetic friction μ that will result in this motion.

a) Draw a sketch showing the box on the incline. Include all relevant variables in the sketch. Draw a *separate* freebody diagram for the box while it is moving up the incline.



b) Make a force table that has a row for each force acting on the box, and two columns for two appropriate orthogonal directions. Fill in the force table with the components of each force in each direction.

	$\nearrow^+$	$\nwarrow^+$
$m\vec{g}$	$-mg\sin\theta$	$-mg\cos\theta$
$\vec{P}$	$P\cos\theta$	$-P\sin\theta$
$\vec{f}$	$-f$	0
$\vec{N}$	0	N

c) By using Newton's Second Law in each direction, find an expression for μ, the coefficient of friction needed for the box to move at constant speed up the ramp.

$$\nearrow^+: -mg\sin\theta + P\cos\theta - f = 0 \implies f = P\cos\theta - mg\sin\theta$$
$$\nwarrow^+: -mg\cos\theta - P\sin\theta + N = 0 \implies N = P\sin\theta + mg\cos\theta$$
$$\mu = \frac{f}{N} = \boxed{\frac{P\cos\theta - mg\sin\theta}{P\sin\theta + mg\cos\theta}}$$

d) If $P = 20\,\text{N}$, $m = 1.0\,\text{kg}$, and $\theta = 30°$, determine the numerical value for μ.

$$\mu = \frac{(20\,\text{N})\cos 30° - (1.0\,\text{kg})(9.8\,\text{m/s}^2)\sin 30°}{(20\,\text{N})\sin 30° + (1.0\,\text{kg})(9.8\,\text{m/s}^2)\cos 30°} = \boxed{0.67}$$