18. We use coordinates and weight-components as indicated in Fig. 5-18 (see Sample Problem 5-7 from the previous chapter).

(a) In this situation, we take $\vec{f_s}$ to point uphill and to be equal to its maximum value, in which case $f_{s,\max} = \mu_s N$ applies, where $\mu_s = 0.25$. Applying Newton's second law to the block of mass $m = W/g = 8.2$ kg, in the x and y directions, produces

$$\begin{aligned} F_{\min 1} - mg\sin\theta + f_{s,\max} &= ma = 0 \\ N - mg\cos\theta &= 0 \end{aligned}$$

which (with $\theta = 20°$) leads to

$$F_{\min 1} = mg\,(\sin\theta - \mu_s\cos\theta) = 8.6 \text{ N} .$$

(b) Now we take $\vec{f_s}$ to point downhill and to be equal to its maximum value, in which case $f_{s,\max} = \mu_s N$ applies, where $\mu_s = 0.25$. Applying Newton's second law to the block of mass $m = W/g = 8.2$ kg, in the x and y directions, produces

$$\begin{aligned} F_{\min 2} - mg\sin\theta - f_{s,\max} &= ma = 0 \\ N - mg\cos\theta &= 0 \end{aligned}$$

which (with $\theta = 20°$) leads to

$$F_{\min 2} = mg\,(\sin\theta + \mu_s\cos\theta) = 46 \text{ N} .$$

A value slightly larger than the "exact" result of this calculation is required to make it accelerate up hill, but since we quote our results here to two significant figures, 46 N is a "good enough" answer.

(c) Finally, we are dealing with kinetic friction (pointing downhill), so that

$$\begin{aligned} F - mg\sin\theta - f_k &= ma = 0 \\ N - mg\cos\theta &= 0 \end{aligned}$$

along with $f_k = \mu_k N$ (where $\mu_k = 0.15$) brings us to

$$F = mg\,(\sin\theta + \mu_k\cos\theta) = 39 \text{ N} .$$