83. (Fifth problem in **Cluster 1**)
A useful diagram (where these forces are analyzed) is Fig. 6-5 in the textbook. In that figure, W is the weight (equal to $mg = 98$ N).

(a) Since there is no motion, then $\sum \vec{F} = 0$ along the incline, so $f_s - W \sin\theta = 0$ (if uphill is positive, which is the direction assumed for $\vec{f_s}$). We therefore obtain $f_s = 25$ N. Our result is positive, so it indeed points uphill as we had assumed. One can check that this value of f_s does not exceed the maximum possible value $f_{s,\,\max}$ (see next part).

(b) As in part (a), we have $f_s - W \sin\theta = 0$, but since the system is on the verge of motion we also have $f_s = f_{s,\,\max} = \mu_s W \cos\theta$. Therefore,

$$\mu_s W \cos\theta - W \sin\theta = 0 \quad \Longrightarrow \quad \mu_s = \tan\theta$$

which leads to $\theta_s = \tan^{-1} \mu_s = 31°$ (this is often called "the angle of repose").

(c) If the block slides with no acceleration then we have $f_k - W \sin\theta = 0$ from Newton's second law applied along the incline surface. With $f_k = \mu_k W \cos\theta$ we are led to $\theta_k = \tan^{-1} \mu_k$ as the condition for this constant velocity sliding downhill. Since $\mu_k < \mu_s$ then we see that $\theta_k < \theta_s$ from part (b).

(d) We find $\theta_k = \tan^{-1} \mu_k = 11°$.