12. We denote the magnitude of 110 N force exerted by the worker on the crate as F. The magnitude of the static frictional force can vary between zero and $f_{s,\,\max} = \mu_s N$.

   (a) In this case, application of Newton's second law in the vertical direction yields $N = mg$. Thus,

$$\begin{aligned} f_{s,\,\max} &= \mu_s N = \mu_s mg \\ &= (0.37)(35\,\text{kg})\left(9.8\,\text{m/s}^2\right) = 126.9\text{ N} \end{aligned}$$

   which is greater than F. The block, which is initially at rest, stays at rest. This implies, by applying Newton's second law to the horizontal direction, that the magnitude of the frictional force exerted on the crate is $f_s = F = 110\,\text{N}$.

   (b) As calculated in part (a), $f_{s,\,\max} = 1.3 \times 10^2\,\text{N}$.

   (c) As remarked above, the crate does not move (since $F < f_{s,\,\max}$).

   (d) Denoting the upward force exerted by the second worker as F_2, then application of Newton's second law in the vertical direction yields $N = mg - F_2$. Therefore, in this case, $f_{s,\,\max} = \mu_s N = \mu_s(mg - F_2)$. In order to move the crate, F must satisfy $F > f_{s,\,\max} = \mu_s(mg - F_2)$, i.e.,

$$110\,\text{N} > (0.37)\left((35\,\text{kg})\left(9.8\,\text{m/s}^2\right) - F_2\right) .$$

   The minimum value of F_2 that satisfies this inequality is a value slightly bigger than 45.7 N, so we express our answer as $F_{2,\,\min} = 46\,\text{N}$.

   (e) In this final case, moving the crate requires a greater horizontal push from the worker than static friction (as computed in part (a)) can resist. Thus, Newton's law in the horizontal direction leads to

$$\begin{aligned} F + F_2 &> f_{s,\,\max} \\ 110\,\text{N} + F_2 &> 126.9\,\text{N} \end{aligned}$$

   which leads (after appropriate rounding) to $F_{2,\,\min} = 17\,\text{N}$.