Chapter 7++

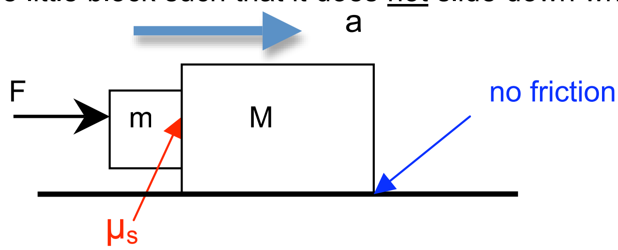
Revisit Friction Force

Revisit:	To-Do:
• Friction modeling • Block-on-block problems	• Accelerating block-against-block problem where the normal force is certainly not due to gravity

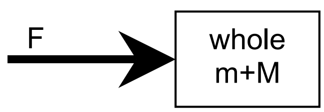
Accelerating Block-Against-Block Example

Important Tactic: First consider the whole body. Then consider pieces of it.

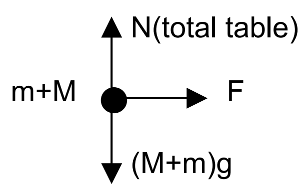
Two blocks, with masses m and M as shown, have a static coefficient μ_s of friction between them, and the big block has negligible friction between it and the surface beneath. A sufficiently large force F is applied to the little block such that it does <u>not</u> slide down while the whole system accelerates:



a) Find the horizontal acceleration a of the whole two-block system in terms of the parameters given. The only external horizontal force is F; the horizontal force diagram and the FBD are



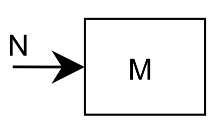
overall FBD:



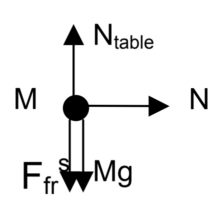
leading to the second law for the horizontal motion:

$$\Rightarrow\ F = (m+M)a \ \Rightarrow\ \boxed{a = \frac{F}{m+M}}$$

b) Find the normal contact force N between the little block and the big block in terms of given parameters (we ultimately want the friction force). For the big block, the only horizontal force is the N. This contact force is the direct cause of its horizontal acceleration; F does NOT have direct contact and only indirectly causes N! The horizontal force diagram and the FBD are



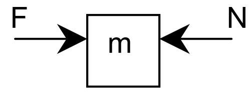
M FBD:



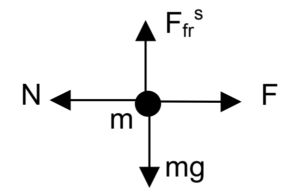
leading to the second law for the horizontal motion:

$$\Rightarrow\ N = Ma \ \Rightarrow \boxed{N = \frac{M}{m+M}F}$$

c) The alternative approach to finding N is to consider the little block since N is relevant to it, too, using Newton's third law. It feels two horizontal forces. The horizontal force diagram and the FBD are



m FBD:



leading to the second law for the horizontal motion and a formula for N that agrees with the previous answer

$$\Rightarrow \quad F - N = ma \quad \Rightarrow N = F - ma = F - \frac{m}{m+M}F = \left(1 - \frac{m}{m+M}\right)F = \frac{M}{m+M}F$$

d) Finally, we can analyze the friction for the vertical motion and ask, "How small can μ_s be before the small block will start to slide?" The vertical force balance picture and equation are

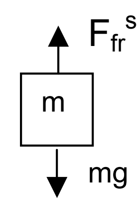
$$F_{fr}^{s} - mg = 0$$

$$F_{fr}^{s} = mg$$

$$\text{but } F_{fr}^{s} \le \mu_s N \text{ (or else it slides)}$$

$$\Rightarrow mg \le \mu_s \frac{M}{m+M}F$$

$$\Rightarrow \mu_s \ge mg\frac{1}{\frac{M}{m+M}F}$$



$$\boxed{\mu_s \ge \frac{mg}{F}\frac{m+M}{M}} \text{ or else slides down!}$$

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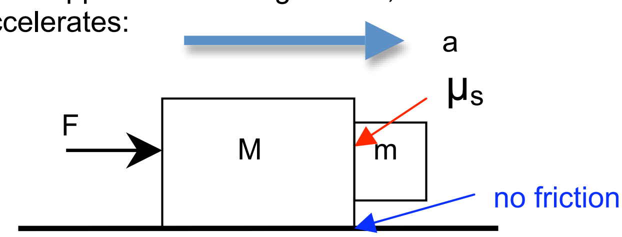
Problem 7-6 Two blocks, with masses m and M as shown, have a static coefficient μ_s of friction between them, and the big block has negligible friction between it and the surface beneath. A sufficiently large horizontal force F is applied to the large block, such that the little block does not slide down, while the system accelerates:



a) Draw an FBD and then find the acceleration a for the whole system of two blocks.
b) Draw an FBD for the little block and then find the normal contact force N between the little block and the big block.
c) How small can μ_s be before the small block will start to slide down?
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