The tension in the cable pulls upward on the seat and, simultaneously, pulls downward on the motor and supports at the top of the lift.

The Massless String Approximation

The tension is constant throughout a rope that is in equilibrium, but what happens if the rope is accelerating? For example, FIGURE 7.22a shows two connected blocks being pulled by force $\vec{F}$. Is the string's tension at the right end, where it pulls back on B, the same as the tension at the left end, where it pulls on A?

FIGURE 7.22 The string's tension pulls forward on block A, backward on block B.

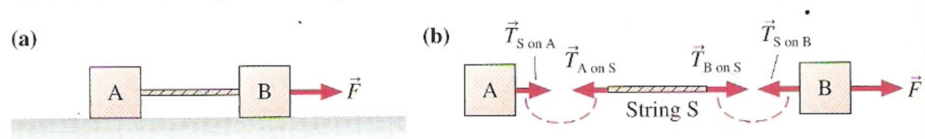


FIGURE 7.22b shows the horizontal forces acting on the blocks and the string. If the string is accelerating, then it must have a net force applied to it. The only forces acting on the string are $\vec{T}_{\text{A on S}}$ and $\vec{T}_{\text{B on S}}$, so Newton's second law *for the string* is

$$(F_{\text{net}})_x = T_{\text{B on S}} - T_{\text{A on S}} = m_s a_x \qquad (7.7)$$

where m_s is the mass of the string.

If the string is accelerating, then the tensions at the two ends can *not* be the same. In fact, you can see that

$$T_{\text{B on S}} = T_{\text{A on S}} + m_s a_x \qquad (7.8)$$

The tension at the "front" of the string is higher than the tension at the "back." This difference in the tensions is necessary to accelerate the string! On the other hand, the tension is constant throughout a string in equilibrium ($a_x = 0$). This was the situation in Example 7.5.

Often in physics and engineering problems the mass of the string or rope is much less than the masses of the objects that it connects. In such cases, we can adopt the **massless string approximation.** In the limit $m_s \to 0$, Equation 7.8 becomes

$$T_{\text{B on S}} = T_{\text{A on S}} \quad \text{(massless string approximation)} \qquad (7.9)$$

In other words, **the tension in a massless string is constant.** This is nice, but it isn't the primary justification for the massless string approximation.

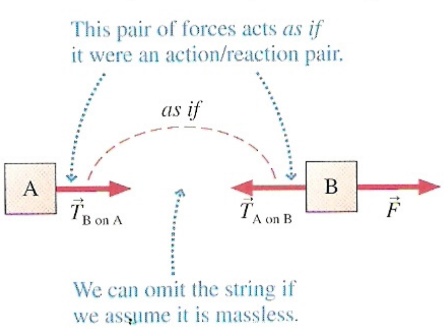
Look again at Figure 7.22b. If $T_{\text{B on S}} = T_{\text{A on'S}}$, then

$$\vec{T}_{\text{S on A}} = -\vec{T}_{\text{S on B}} \qquad (7.10)$$

That is, the force on block A is equal and opposite to the force on block B. Forces $\vec{T}_{\text{S on A}}$ and $\vec{T}_{\text{S on B}}$ act *as if* they are an action/reaction pair of forces. Thus we can draw the simplified diagram of FIGURE 7.23 in which the string is missing and blocks A and B interact directly with each other through forces that we can call $\vec{T}_{\text{A on B}}$ and $\vec{T}_{\text{B on A}}$.

In other words, **if objects A and B interact with each other through a massless string, we can omit the string and treat forces $\vec{F}_{\text{A on B}}$ and $\vec{F}_{\text{B on A}}$ *as if* they are an action/reaction pair.** This is not literally true because A and B are not in contact. Nonetheless, all a massless string does is transmit a force from A to B without changing the magnitude of that force. This is the real significance of the massless string approximation.

FIGURE 7.23 The massless string approximation allows objects A and B to act *as if* they are directly interacting.



NOTE ▶ For problems in this book, you can assume that any strings or ropes are massless unless the problem explicitly states otherwise. The simplified view of Figure 7.23 is appropriate under these conditions. But if the string has a mass, it must be treated as a separate object. ◀