



FIGURE 4-15 Example 4-6. (a) A 10-kg gift box is at rest on a table. (b) A person pushes down on the box with a force of 40.0 N. (c) A person pulls upward on the box with a force of 40.0 N. The forces are all assumed to act along a line; they are shown slightly displaced in order to be distinguishable. Only forces acting on the box are shown.

CAUTION
The normal force is not necessarily equal to the weight

CAUTION
The normal force, \vec{F}_N , is not necessarily vertical

EXAMPLE 4-6 Weight, normal force, and a box. A friend has given you a special gift, a box of mass 10.0 kg with a mystery surprise inside. The box is resting on the smooth (frictionless) horizontal surface of a table (Fig. 4-15a). (a) Determine the weight of the box and the normal force exerted on it by the table. (b) Now your friend pushes down on the box with a force of 40.0 N, as in Fig. 4-15b. Again determine the normal force exerted on the box by the table. (c) If your friend pulls upward on the box with a force of 40.0 N (Fig. 4-15c), what now is the normal force exerted on the box by the table?

APPROACH The box is at rest on the table, so the net force on the box in each case is zero (Newton's second law). The weight of the box equals mg in all three cases.

SOLUTION (a) The weight of the box is $mg = (10.0 \text{ kg})(9.80 \text{ m/s}^2) = 98.0 \text{ N}$, and this force acts downward. The only other force on the box is the normal force exerted upward on it by the table, as shown in Fig. 4-15a. We chose the upward direction as the positive y direction; then the net force ΣF_y on the box is $\Sigma F_y = F_N - mg$. The box is at rest, so the net force on it must be zero (Newton's second law, $\Sigma F_y = ma_y$, and $a_y = 0$). Thus

$$\Sigma F_y = F_N - mg = 0,$$

and we have in this case

$$F_N = mg.$$

The normal force on the box, exerted by the table, is 98.0 N upward, and has magnitude equal to the box's weight.

(b) Your friend is pushing down on the box with a force of 40.0 N. So instead of only two forces acting on the box, now there are three forces acting on the box, as shown in Fig. 4-15b. The weight of the box is still $mg = 98.0 \text{ N}$. The net force is $\Sigma F_y = F_N - mg - 40.0 \text{ N}$, and is equal to zero because the box remains at rest. Thus, since $a = 0$, Newton's second law gives

$$\Sigma F_y = F_N - mg - 40.0 \text{ N} = 0.$$

We solve this equation for the normal force:

$$F_N = mg + 40.0 \text{ N} = 98.0 \text{ N} + 40.0 \text{ N} = 138.0 \text{ N},$$

which is greater than in (a). The table pushes back with more force when a person pushes down on the box. The normal force is not always equal to the weight!

(c) The box's weight is still 98.0 N and acts downward. The force exerted by your friend and the normal force both act upward (positive direction), as shown in Fig. 4-15c. The box doesn't move since your friend's upward force is less than the weight. The net force, again set to zero in Newton's second law because $a = 0$, is

$$\Sigma F_y = F_N - mg + 40.0 \text{ N} = 0,$$

so

$$F_N = mg - 40.0 \text{ N} = 98.0 \text{ N} - 40.0 \text{ N} = 58.0 \text{ N}.$$

The table does not push against the full weight of the box because of the upward pull exerted by your friend.

NOTE The weight of the box ($=mg$) does not change as a result of your friend's push or pull. Only the normal force is affected.

Recall that the normal force is elastic in origin (the table in Fig. 4-15 sags slightly under the weight of the box). The normal force in Example 4-6 is vertical, perpendicular to the horizontal table. The normal force is not always vertical, however. When you push against a vertical wall, for example, the normal force with which the wall pushes back on you is horizontal. For an object on a plane inclined at an angle to the horizontal, such as a skier or car on a hill, the normal force acts perpendicular to the plane and so is not vertical.