

and other structures, since any material will buckle or break if too much force is applied (Fig. 9–1). In the human body a knowledge of the forces in muscles and joints is of great value for doctors, physical therapists, and athletes.

9–1 The Conditions for Equilibrium

Objects in daily life have at least one force acting on them (gravity). If they are at rest, then there must be other forces acting on them as well so that the net force is zero. A book at rest on a table, for example, has two forces acting on it, the downward force of gravity and the normal force the table exerts upward on it (Fig. 9–2). Since the net force on the book is zero, the upward force exerted by the table on the book must be equal in magnitude to the force of gravity acting downward on the book. Such an object is said to be in **equilibrium** (Latin for “equal forces” or “balance”) under the action of these two forces.

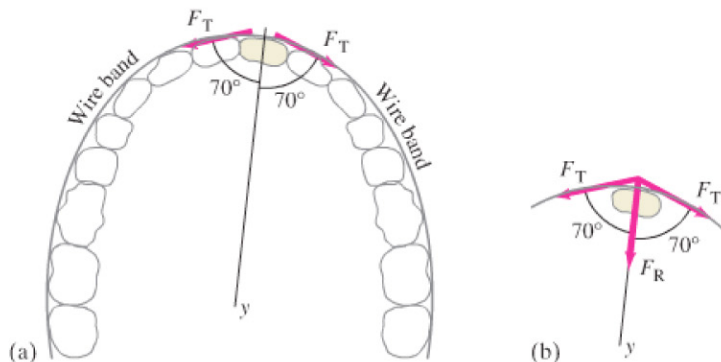
Do not confuse the two forces in Fig. 9–2 with the equal and opposite forces of Newton’s third law, which act on different objects. Here, both forces act on the same object.

EXAMPLE 9–1 Straightening teeth. The wire band shown in Fig. 9–3a has a tension F_T of 2.0 N along it. It therefore exerts forces of 2.0 N on the highlighted tooth (to which it is attached) in the two directions shown. Calculate the resultant force on the tooth due to the wire, F_R .

APPROACH Since the two forces F_T are equal, their sum will be directed along the line that bisects the angle between them, which we have chosen to be the y axis. The x components of the two forces add up to zero.

SOLUTION The y component of each force is $(2.0 \text{ N})(\cos 70^\circ) = 0.684 \text{ N}$; adding the two together, we get a resultant force $F_R = 1.37 \text{ N}$ as shown in Fig. 9–3b. We assume that the tooth is in equilibrium because the gums exert an equal and opposite force. Actually that is not quite so since the objective is to move the tooth ever so slowly.

NOTE If the wire is firmly attached to the tooth, the tension to the right, say, can be made larger than that to the left, and the resultant force would correspondingly be directed more toward the right.



The First Condition for Equilibrium

For an object to be at rest, Newton’s second law tells us that the sum of the forces acting on it must add up to zero. Since force is a vector, the components of the net force must each be zero. Hence, a condition for equilibrium is that

$$\Sigma F_x = 0, \quad \Sigma F_y = 0, \quad \Sigma F_z = 0. \quad (9-1)$$

We will mainly be dealing with forces that act in a plane, so we usually need only the x and y components. We must remember that if a particular force component points along the negative x or y axis, it must have a negative sign. Equations 9–1 are called the **first condition for equilibrium**.



FIGURE 9–1 Elevated walkway collapse in a Kansas City hotel in 1981. How a simple physics calculation could have prevented the tragic loss of over 100 lives is considered in Example 9–12.



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FIGURE 9–2 The book is in equilibrium; the net force on it is zero.

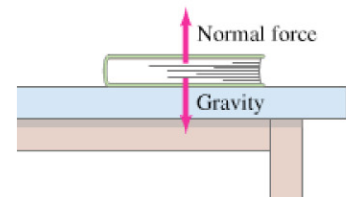


FIGURE 9–3 Forces on a tooth. Example 9–1.

*First condition for equilibrium:
the sum of all forces is zero*