*Parallelogram method of adding vectors*

A second way to add two vectors is the **parallelogram method**. It is fully equivalent to the tail-to-tip method. In this method, the two vectors are drawn starting from a common origin, and a parallelogram is constructed using these two vectors as adjacent sides as shown in Fig. 3–6b. The resultant is the diagonal drawn from the common origin. In Fig. 3–6a, the tail-to-tip method is shown, and it is clear that both methods yield the same result.

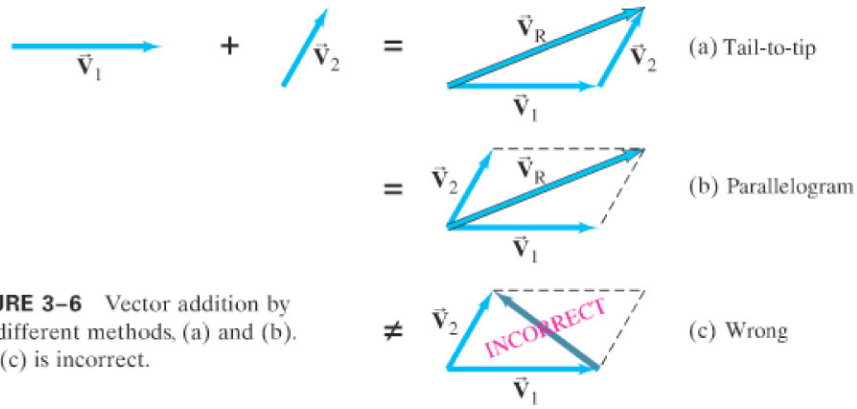


**FIGURE 3–6** Vector addition by two different methods, (a) and (b). Part (c) is incorrect.

**CAUTION**

*Be sure to use the correct diagonal on parallelogram to get the resultant*

It is a common error to draw the sum vector as the diagonal running between the tips of the two vectors, as in Fig. 3–6c. *This is incorrect*: it does not represent the sum of the two vectors. (In fact, it represents their difference, $\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1$, as we will see in the next Section.)

**CONCEPTUAL EXAMPLE 3–1** **Range of vector lengths.** Suppose two vectors each have length 3.0 units. What is the range of possible lengths for the vector representing the sum of the two?

**RESPONSE** The sum can take on any value from 6.0 $(= 3.0 + 3.0)$ where the vectors point in the same direction, to 0 $(= 3.0 - 3.0)$ when the vectors are antiparallel.

**EXERCISE B** If the two vectors of Conceptual Example 3–1 are perpendicular to each other, what is the resultant vector length?

## 3–3 Subtraction of Vectors, and Multiplication of a Vector by a Scalar

Given a vector $\vec{\mathbf{V}}$, we define the *negative* of this vector $(-\vec{\mathbf{V}})$ to be a vector with the same magnitude as $\vec{\mathbf{V}}$ but opposite in direction, Fig. 3–7. Note, however, that no vector is ever negative in the sense of its magnitude: the magnitude of every vector is positive. Rather, a minus sign tells us about its direction.


**FIGURE 3–7** The negative of a vector is a vector having the same length but opposite direction.

We can now define the subtraction of one vector from another: the difference between two vectors $\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1$ is defined as

$$\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1 = \vec{\mathbf{V}}_2 + (-\vec{\mathbf{V}}_1).$$

That is, the difference between two vectors is equal to the sum of the first plus the negative of the second. Thus our rules for addition of vectors can be applied as shown in Fig. 3–8 using the tail-to-tip method.

**FIGURE 3–8** Subtracting two vectors: $\vec{\mathbf{V}}_2 - \vec{\mathbf{V}}_1$.