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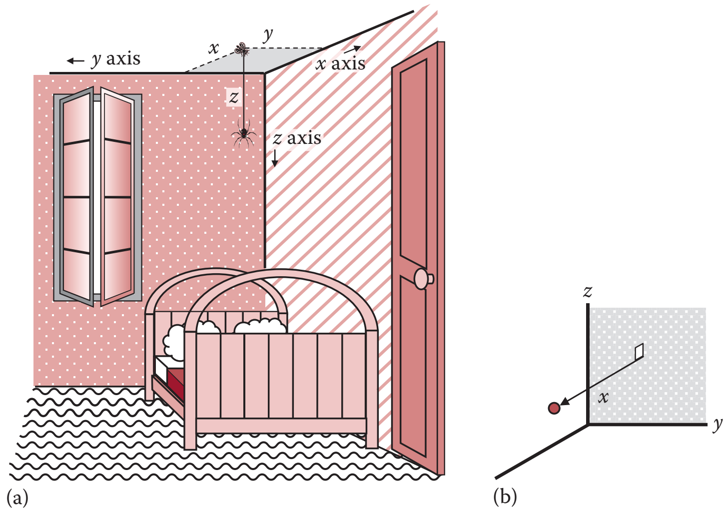

Figure 2.1 (a) A fly rests on the ceiling near one corner of a room. The perpendicular distance from each wall defines the fly's *x*- and *y*-coordinates. The *z*-coordinate of a spider hanging below the ceiling is defined as its perpendicular distance from the ceiling. The *x*-, *y*- and *z*-axes lie along the intersections of the ceiling with each wall, and along the intersection of the two walls. (b) A Cartesian coordinate system. The *x*-coordinate of a body is its perpendicular distance from the *y*–*z* plane, and likewise for the *y*- and *z*-coordinates.

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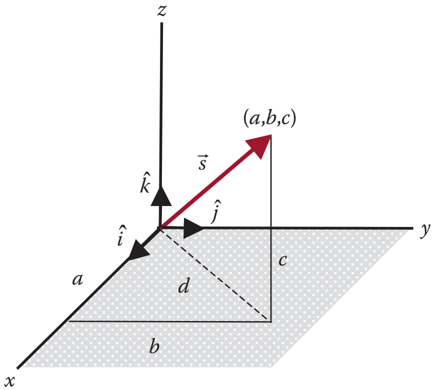

Figure 2.2 Starting at the origin (0, 0, 0) you travel a meters in the east or $\hat{i}$ direction, then b meters in the north or $\hat{j}$ direction, and then ascend the stairs c meters in the vertical $\hat{k}$ direction. Your overall displacement from the origin $\vec{s} = a\hat{i} + b\hat{j} + c\hat{k}$ is depicted by the arrow drawn from your initial position to your final position.

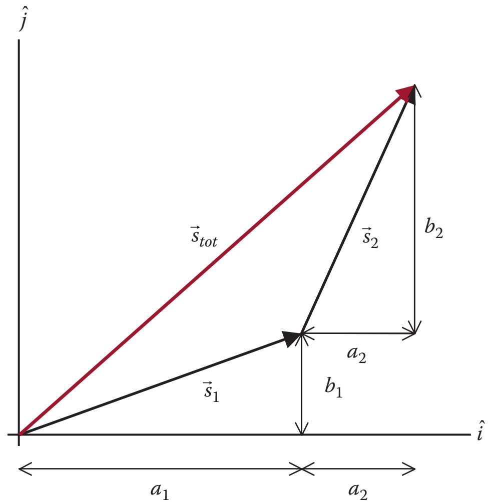

Figure 2.3 Vector additions of two successive displacements. For simplicity, the two displacements are confined to the x–y plane. The final position could have been reached by first traveling $(a_1 + a_2)$ meters in the $\hat{i}$ direction and then proceeding $(b_1 + b_2)$ meters in the $\hat{j}$ direction.

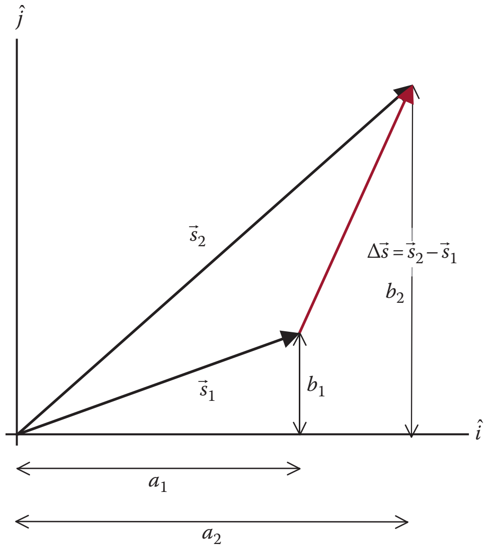

Figure 2.4 Vector subtraction: $\Delta\vec{s} = \vec{s}_2 - \vec{s}_1$. Note the direction of $\Delta\vec{s}$, which conforms to the rules of vector addition, $\vec{s}_1 + \Delta\vec{s} = \vec{s}_2$.

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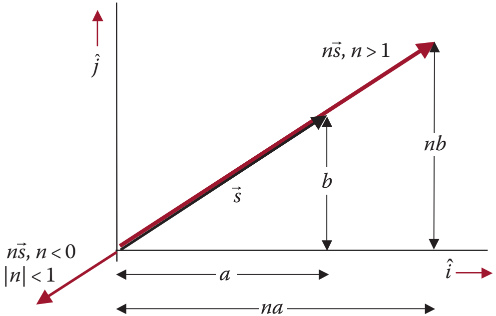

Figure 2.5 Multiplication of vector $\vec{s}$ by a scalar n. Depending on n, the original vector is stretched ($n > 1$), shrunk ($0 < n < 1$), or has its direction reversed ($n < 0$).

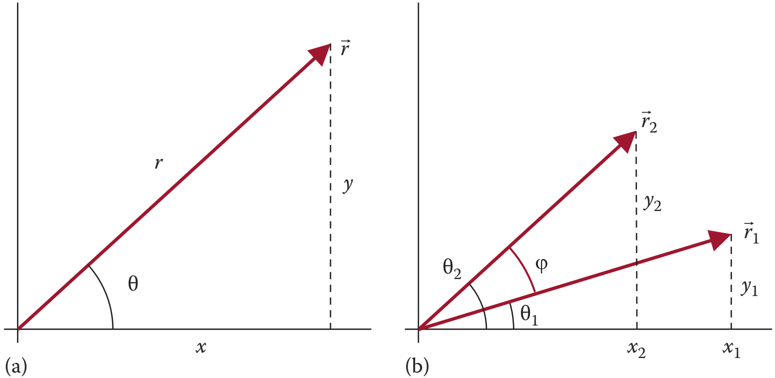

Figure 2.6 (a) Vector $\vec{r}$ makes an angle $\theta = \cos^{-1}(x/r)$ with the x- or $\hat{i}$ axis. (b) Vectors $\vec{r}_1 = x_1\hat{i} + y_1\hat{j}$, $\vec{r}_2 = x_2\hat{i} + y_2\hat{j}$ make angles θ_1 and θ_2 with the x-axis. The angle between the vectors is θ.

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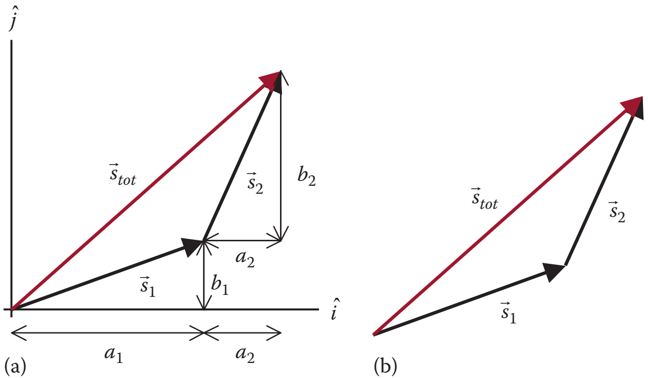

Figure 2.7 Vector addition: (a) with coordinate axes shown and (b) without coordinate axes.

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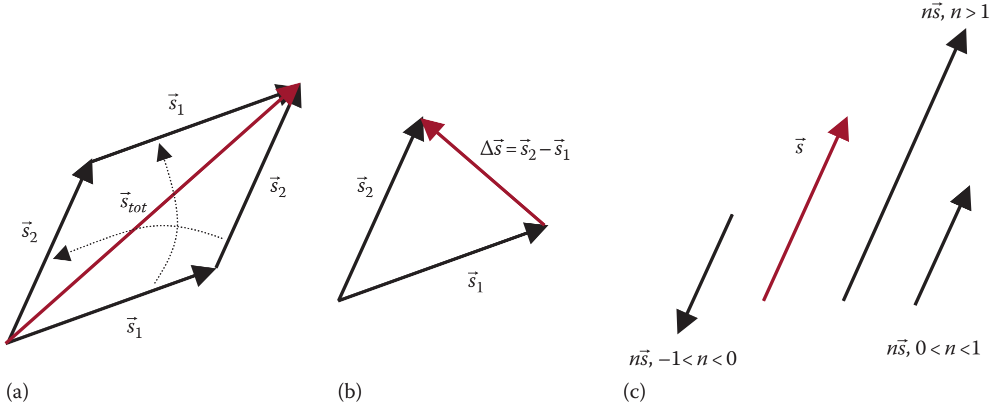

Figure 2.8 (a) $\vec{s}_{tot} = \vec{s}_1 + \vec{s}_2$. Transposing $\vec{s}_1$ and $\vec{s}_2$, $\vec{s}_{tot} = \vec{s}_2 + \vec{s}_1$ showing that vector addition is commutative. The original two vectors plus their transposed copies form a parallelogram. (b) Vector subtraction $\Delta\vec{s} = \vec{s}_2 - \vec{s}_1$ without coordinate axes. The vectors $\vec{s}_1$ and $\vec{s}_2$ are arranged with their tails attached and $\Delta\vec{s}$ points from the tip of the $\vec{s}_1$ to the tip of $\vec{s}_2$. (c) Vector multiplication by a scalar n.

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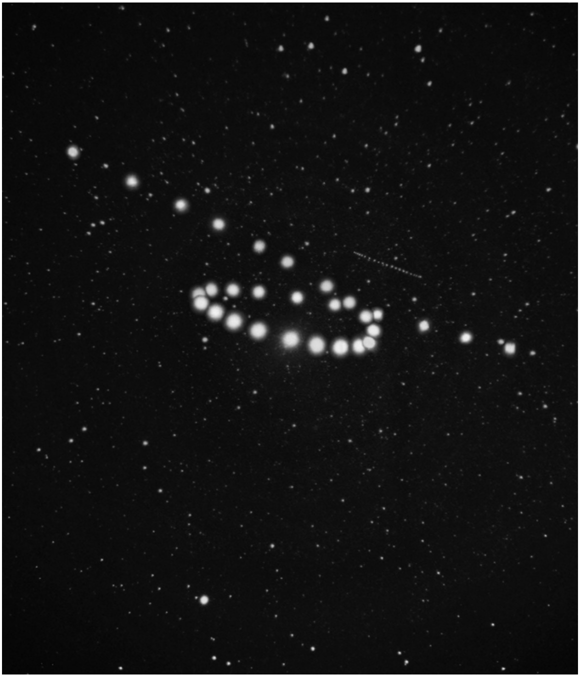

Figure 2.9 Retrograde motion of Mars from June to December, 2003. Each of the superimposed images was taken about 1 week apart, with the earliest image to the right (west). The brightest image occurred when the Earth and Mars were closest to each other. The faint dotted line in the background is the planet Uranus. (Photo: Tunç Tezel, Bursa, Turkey.)

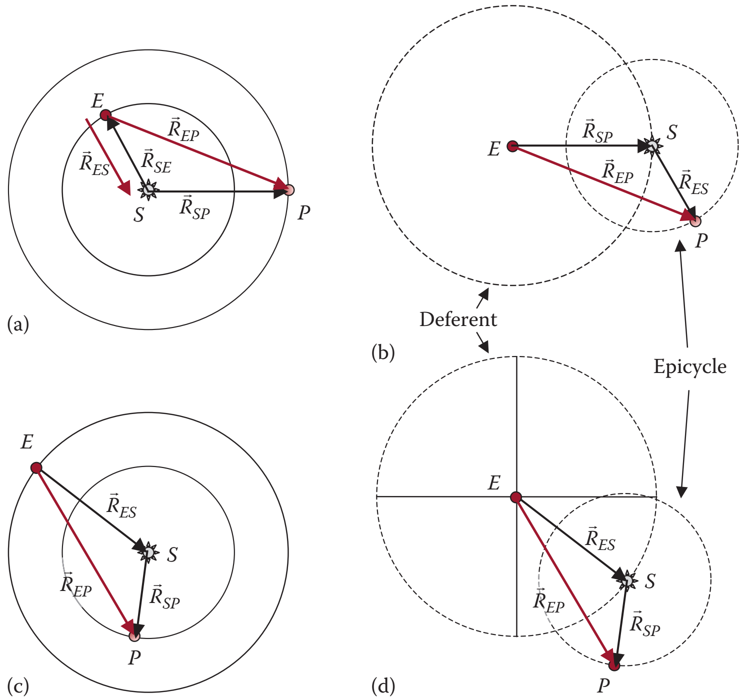

Figure 2.10 (a) The Earth (E), Sun (S), and superior planet (P) according to the Copernican model. (b) The same configuration as in (a), but $\vec{R}_{SP}$ and $\vec{R}_{ES}$ $(=-\vec{R}_{SE})$ have been translated to new positions to show the equivalence with the Ptolemaic model. The dotted lines show the deferent and epicycle of planet P. The orbit of an inferior planet (P) is shown in the (c) Copernican and (d) Ptolemaic models. In this case, the deferent has a length 1 AU and an epicycle with the same radius as the planet's heliocentric orbit.

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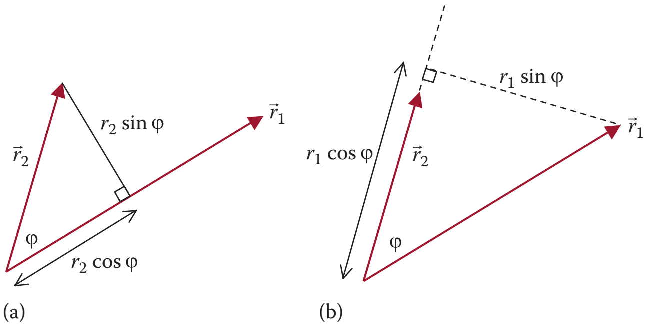

Figure 2.11 The dot product $\vec{r}_1 \cdot \vec{r}_2 = r_1 r_2 \cos\varphi$ without coordinate axes. (a) $r_2 \cos\varphi$ is the component of $\vec{r}_2$ parallel to $\vec{r}_1$ and (b) $r_1 \cos\varphi$ is the component of $\vec{r}_1$ parallel to $\vec{r}_2$.

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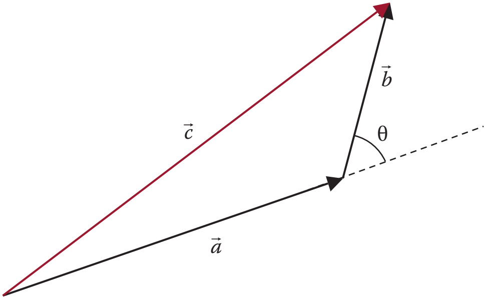

Figure 2.12 Illustrating the law of cosines. θ is the angle between the direction of $\vec{a}$ and $\vec{b}$. Note that this is the exterior angle of the triangle.

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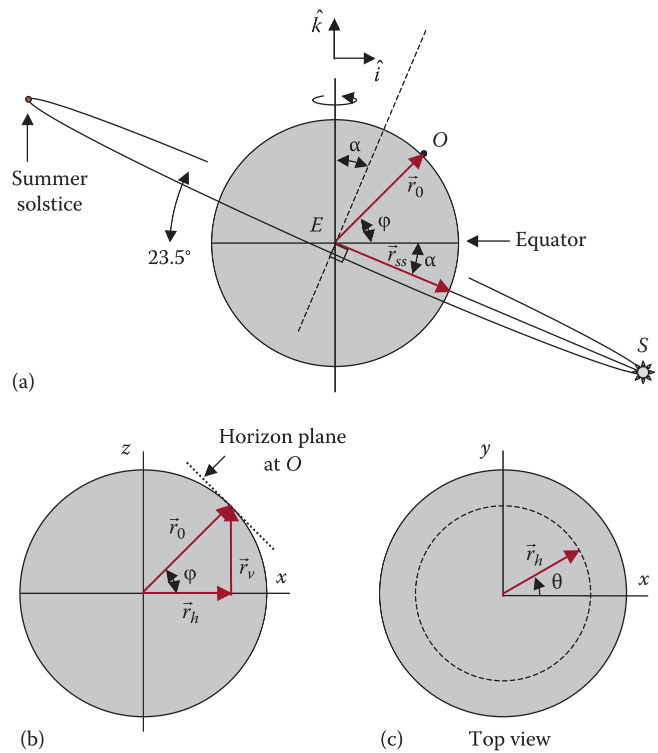

Figure 2.13 (a) Earth and Sun on the December solstice. In the Ptolemaic picture, the Sun revolves about Earth once each year. (The Sun and its orbit are not shown to scale.) Angle α is the planet's axial tilt, angle φ is the latitude of O, and the dotted line is perpendicular to the plane of the Sun's orbit. Angle φ is the latitude of the observation point O. The subsolar point is located at $\vec{r}_{ss}$ on the line between the Earth and Sun. As the year passes, $\vec{r}_{ss}$ rotates in the plane of the orbit. (b) Vector $\vec{r}_O = \vec{r}_v + \vec{r}_h$, where $r_h = R_E \cos\varphi$. (c) Top view of (b). Due to the Earth's daily rotation, the horizontal component $\vec{r}_h$ sweeps out a full circle once per day.

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