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Enlightening Interdisciplinarity in STEM for Teaching

Linguistic analysis of textbooks (Physics, volume 1, by James S. Walker, 2017)

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The Walker's textbook:

Observing the textual and syntactical structures, we can see that the sentences are brief, primarily coordinated, or in implicit subordination without expressing logical relations among the clauses' contents. That means the logical relations might remain obscure to the readers.

In addition, the text, and its content, are structured through words as *to begin*, *first*, *and next*. This way of structuring the text seems to suggest a representation of Physics as a sequence of steps to do in order to have a result (a procedure).

Constant Velocity

To begin, consider the simple situation shown in **FIGURE 4-1**. A turtle starts at the origin at $t = 0$ and moves with a constant speed $v_0 = 0.26$ m/s in a direction 25° above the x axis. How far has the turtle moved in the x and y directions after 5.0 seconds?

First, notice that the turtle moves in a straight line a distance given by speed multiplied by time:

$$d = v_0 t = (0.26\ \text{m/s})(5.0\ \text{s}) = 1.3\ \text{m}$$

This is indicated in Figure 4-1 (a). From the definitions of sine and cosine given in the previous chapter, we see that the horizontal (x) and vertical (y) distances are given by

$$x = d\cos 25° = 1.2\ \text{m}$$
$$y = d\sin 25° = 0.55\ \text{m}$$

An alternative way to approach this problem is to treat the x and y motions separately. First, we determine the speed of the turtle in each direction. Referring to Figure 4-1 (b), we see that the x component of velocity is

$$v_{0x} = v_0\cos 25° = 0.24\ \text{m/s}$$

Similarly, the y component of velocity is

$$v_{0y} = v_0\sin 25° = 0.11\ \text{m/s}$$

Next, we find the distance traveled by the turtle in the x and y directions by multiplying the speed in each direction by the time:

$$x = v_{0x}t = (0.24\ \text{m/s})(5.0\ \text{s}) = 1.2\ \text{m}$$
$$y = v_{0y}t = (0.11\ \text{m/s})(5.0\ \text{s}) = 0.55\ \text{m}$$

This is in agreement with our previous results. To summarize, we can think of the turtle's actual motion as a combination of separate x and y motions.

What do you see here?

Constant Acceleration

To study motion with constant acceleration in two dimensions we repeat what was done in one dimension in Chapter 2, but with separate equations for both x and y. For example, to obtain x as a function of time we start with $x = x_0 + v_0 t + \frac{1}{2}at^2$ (Equation 2-11) and replace both v_0 and a with the corresponding x components, v_{0x} and a_x. This gives

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2 \qquad \text{4-3(a)}$$

To obtain y as a function of time, we write y in place of x in Equation 4-3(a):

$$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \qquad \text{4-3(b)}$$

These are the position-versus-time equations of motion for two dimensions. (In three dimensions we introduce a third coordinate direction and label it z. We would then simply replace x with z in Equation 4-3(a) to obtain z as a function of time.)

The same approach gives velocity as a function of time. Start with Equation 2-7, $v = v_0 + at$, and write it in terms of x and y components. This yields

$$v_x = v_{0x} + a_x t \qquad \text{4-4(a)}$$
$$v_y = v_{0y} + a_y t \qquad \text{4-4(b)}$$

Notice that we simply repeat everything we did for one dimension, only now with separate equations for the x and y components.

Finally, we can write $v^2 = v_0^2 + 2a\Delta x$ in terms of components as well:

$$v_x^2 = v_{0x}^2 + 2a_x\Delta x \qquad \text{4-5(a)}$$
$$v_y^2 = v_{0y}^2 + 2a_y\Delta y \qquad \text{4-5(b)}$$

Our results are listed in Table 4-1.

Parabolic Path

RWP Just what is the shape of the curved path followed by a projectile launched horizontally? This can be found by combining $x = v_0 t$ and $y = h - \frac{1}{2}gt^2$, which allows us to express y in terms of x. First, solve for time using the x equation. This gives

$$t = \frac{x}{v_0}$$

Next, substitute this result into the y equation to eliminate t:

$$y = h - \frac{1}{2}g\left(\frac{x}{v_0}\right)^2 = h - \left(\frac{g}{2v_0^{\,2}}\right)x^2 \qquad 4\text{-}8$$

It follows that y has the form

And here?

$$y = a + bx^2$$

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