References

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The Snowplow Problem Revisited

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A classic problem in elementary differential equations, commonly attributed to R. P. Agnew [*Differential Equations*, McGraw-Hill, 1942, pp. 30–32], is the following:

> One day it started snowing at a heavy and steady rate. A snowplow started out at noon, going 2 miles the first hour and 1 mile the second hour. What time did it start snowing?

The problem is usually solved by setting $t = 0$ at noon, setting up the relevant differential equation, finding its general solution and then using the conditions of the problem to eliminate all the arbitrary constants. This procedure involves a fair amount of algebra which, if not done carefully, can be quite tedious. There is, however, a quick and easy way that avoids most of this algebra. It goes as follows:

Let t denote time, measured in hours, and let $t = 0$ at 1:00 P.M. Let t_0 be the time it started snowing. Let $y(t)$ denote the distance traveled by the snowplow, measured in miles. Let $h(t)$ be the height of the snow at time t, so that $h(t_0) = 0$. Let s denote the rate of the snowfall, measured in any suitable units. Then, since it was snowing at a steady rate, $h(t) = s(t - t_0)$. Assume that the width of the snowplow is one unit and let k be the amount of snow that the plow can remove per unit time. Then we have

$$h(t)\frac{dy}{dt} = k \quad \text{or} \quad \frac{dy}{dt} = \frac{c}{t - t_0},$$

where $c = k/s$. Now (and this is the trick) instead of finding the general solution of this differential equation, we note that

$$2 = c\ln(t - t_0)\Big|_{-1}^{0} \quad \text{and} \quad 1 = c\ln(t - t_0)\Big|_{0}^{1}$$

whence $2\ln[(t_0 - 1)/t_0] = \ln[t_0/(t_0 + 1)]$, and a very little algebra yields $t_0^2 + t_0 - 1 = 0$, so that $t_0 = (-1 - \sqrt{5})/2$.

The Differentiability of Sin *x*

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That $\sin x$ is differentiable with derivative $\cos x$ implies that $\sin x$ has derivative 1 at $x = 0$, i.e.,

$$\lim_{x \to 0} \frac{\sin x}{x} = 1. \tag{1}$$