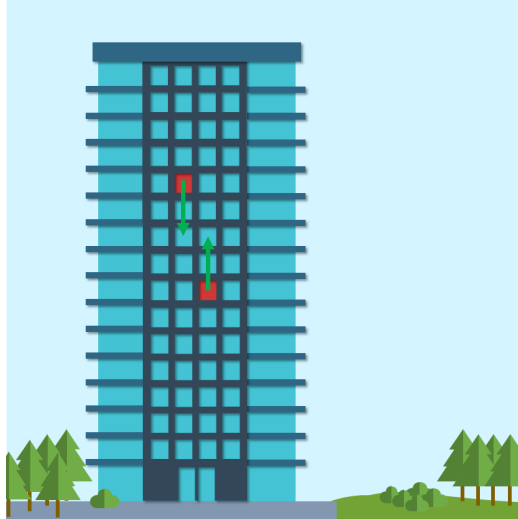


## Elevator in Building



The elevators a skyscraper rise about 350m and for most of its runs have a constant speed of 22km/h. Assume that both the acceleration and deceleration have a constant magnitude of  $0.25g$ . Determine the time duration  $t$  of an elevator run.

*Using known expressions:*

$$a = \frac{dv}{dt} \Rightarrow dv = a dt \quad (1)$$

$$\int_{v_0}^v dv = a \int_0^t dt \quad (2)$$

$$v(t) = a \cdot t + v_0 \quad (3)$$

$$v = \frac{ds}{dt} \Rightarrow ds = v dt = (v_0 + at) dt \quad (4)$$

$$\int_{s_0}^s ds = \int_0^t (v_0 + at) dt \quad (5)$$

$$s(t) = \frac{1}{2}a \cdot t^2 + v_0 \cdot t + s_0 \quad (6)$$

*Given:*

Distance:  $s = 350m$

Acceleration:  $a = 0.25g = 2.4525m/s^2$

Velocity:  $v = 22km/h = 6.11m/s$

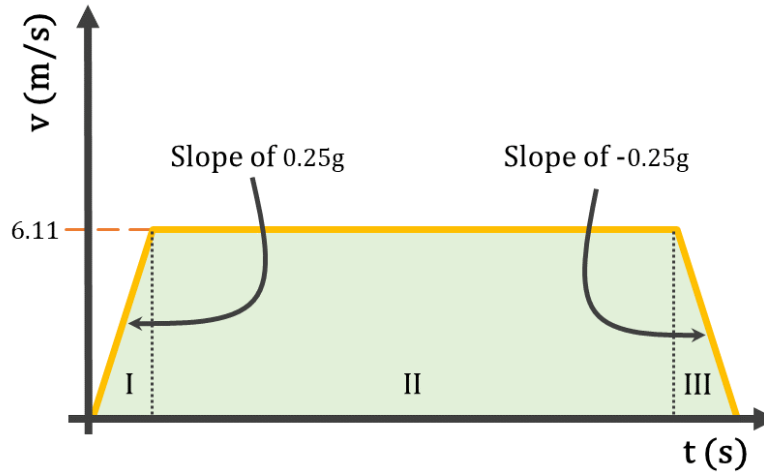


Figure 1: Visualization graph of changing velocity over time

The easiest thing is to visualize the problem by drawing a graph of how the velocity changes over time (see Figure 1). The problem is divided in three parts, the first one is the acceleration of  $a = 0.25g$  of the elevator from standstill ( $v = 0$ ) to its maximum speed of  $v = 6.11 \text{ m/s}$ , then there is a time the elevator has a constant speed of  $6.11 \text{ m/s}$  and finally it decelerates with  $a = -0.25g$  to standstill.

Using Equation 3, the time for the elevator to reach its maximum constant velocity of  $6.11 \text{ m/s}$  from standstill ( $v_0 = 0$ ) can be calculated.

$$t = \frac{v}{a} \Rightarrow t = \frac{6.11}{0.25 \cdot 9.81} = 2.49 \text{ s} \quad (7)$$

The travelled distance in this time is the area of section *I* of Figure 1. It can be directly seen from the figure or calculated using Equation 6, with  $s_0 = v_0 = 0$ .

$$s(t) = \frac{1}{2}a \cdot t^2 + v_0 \cdot t + s_0 = \frac{1}{2}a \cdot t^2 \Rightarrow s(2.49) = \frac{1}{2}0.25 \cdot g \cdot 2.49^2 = 7.61 \text{ m} \quad (8)$$

The elevator both accelerates and decelerates thus the total distance travelled during this motion is  $2 \cdot 7.61 = 15.22 \text{ m}$  (area *I* and area *III* from the figure combined).

To calculate the time the velocity of the elevator is  $6.11 \text{ m/s}$ , we use the fact that the total length is  $350 \text{ m}$  (total area under the curve). Thus the distance the elevator travels at  $v = 6.11 \text{ m/s}$  (or area *II* under the curve) is equal to  $350 - 15.22 = 334.8 \text{ m}$ . Since the velocity is constant the acceleration is 0 thus Equation 6 becomes:

$$s(t) = \frac{1}{2}a \cdot t^2 + v_0 \cdot t + s_0 = v_0 \cdot t \Rightarrow t = \frac{s}{v} = \frac{334.8}{6.11} = 54.79 \text{ s} \quad (9)$$

Thus the total time is  $t = 2.49 + 54.79 + 2.49 = 59.77 \text{ s}$