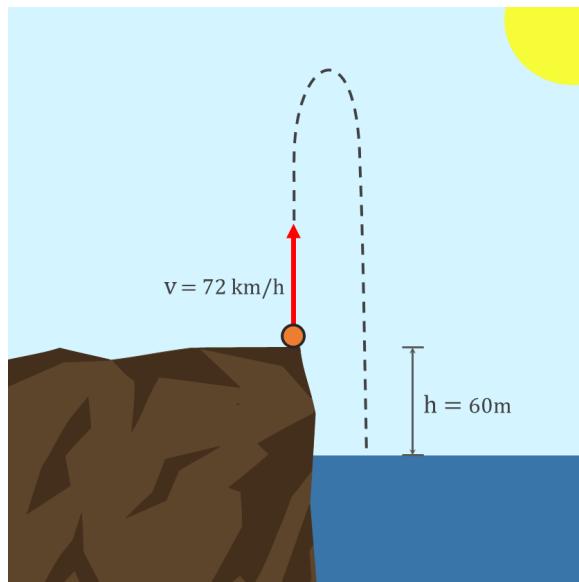


# Ball Thrown from Cliff



A ball is thrown vertically up with an initial vertical velocity of 72 km/h at the edge of a 60 meter high cliff. What is the total time  $t$  in seconds that the ball is in the air? Neglect air resistance and take  $g = 10 \text{ m/s}^2$ .

*Using known expressions:*

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

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

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

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

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

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

For the vertical displacement in y-direction, this results in:

$$y(t) = \frac{1}{2}a_y \cdot t^2 + v_{y,0} \cdot t + s_{y,0} \quad (7)$$

*Given:*

Initial velocity in y-direction:  $v_{y,0} = 72 \text{ km/h} = 20 \text{ m/s}$

Initial height of the ball (with respect to the cliff):  $H_0 = s_{y,0} = 0 \text{ m}$

Gravitational constant:  $g = 10 \text{ m/s}^2$

At the instant the ball reaches the sea, its vertical displacement is  $y = -60 \text{ m}$ . The acceleration on the ball is the gravitational acceleration:  $a_y = -g$ . Combining this into Equation 7 yields an equation for the total time of the ball to reach the sea:

$$y(t) = \frac{1}{2}a_y \cdot t^2 + v_{y,0} \cdot t + s_{y,0} \quad \Rightarrow \quad y(t) = -\frac{1}{2}g \cdot t^2 + v_{y,0} \cdot t \quad (8)$$

Inserting  $y = -60 \text{ m}$ ,  $g = 10 \text{ m/s}^2$  and  $v_{y,0} = 20 \text{ m/s}$  result in:

$$-60 = -\frac{1}{2} \cdot 10 \cdot t^2 + 20 \cdot t \quad \Rightarrow \quad t^2 - 4 \cdot t - 12 = 0 \quad (9)$$

$$t = -2 \text{ s} \quad \vee \quad t = 6 \text{ s} \quad (10)$$

Since  $t$  cannot be negative, the final answer is  $t = 6 \text{ s}$ .