Mousetrap Effect

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Scenario

- An 18-month boy seated on an unpadded, thinly carpeted floor defiantly threw himself backwards somewhat like a mousetrap snapping shut. The resulting occipital blow knocked him unconscious.
- Hospital reports indicated subdural hematomas, brain swelling and retinal hemorrhages. He has since recovered.

7 to |

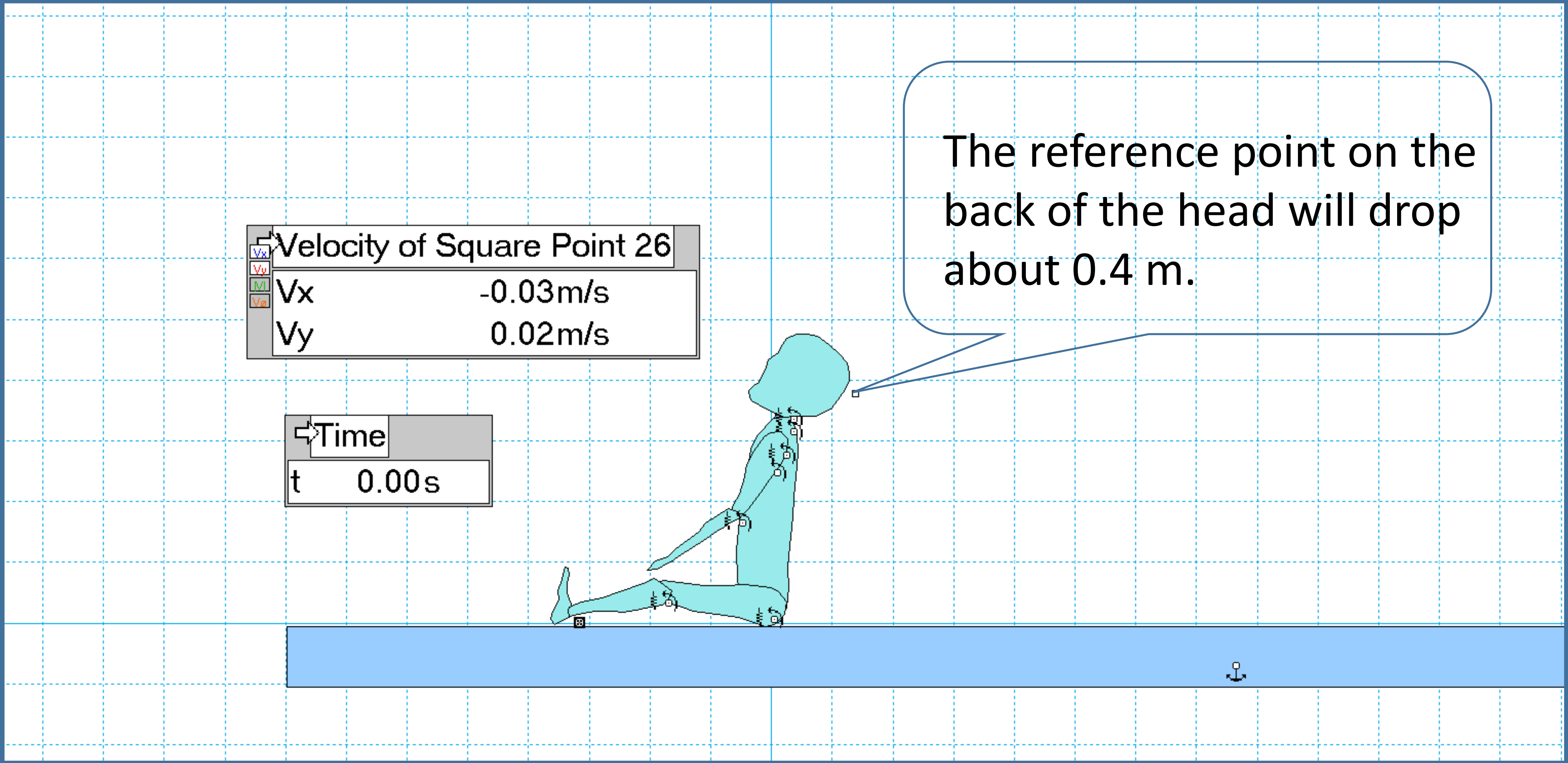
- The result for the vertical impact speed of the head approximates that of a point object falling freely downwards. (See a simple demonstration "Topple Drop" on *YouTube*). However, anyone who can raise up from a bent **7** to an erect **|** position is capable of at least matching the work done by gravity on the upper portion of the body. If this action were applied during the backwards topple, the vertical impact velocity of the head, contact force and angular acceleration could increase by a factor of about $\sqrt{2} \cong 1.4$ over that due to gravity alone.

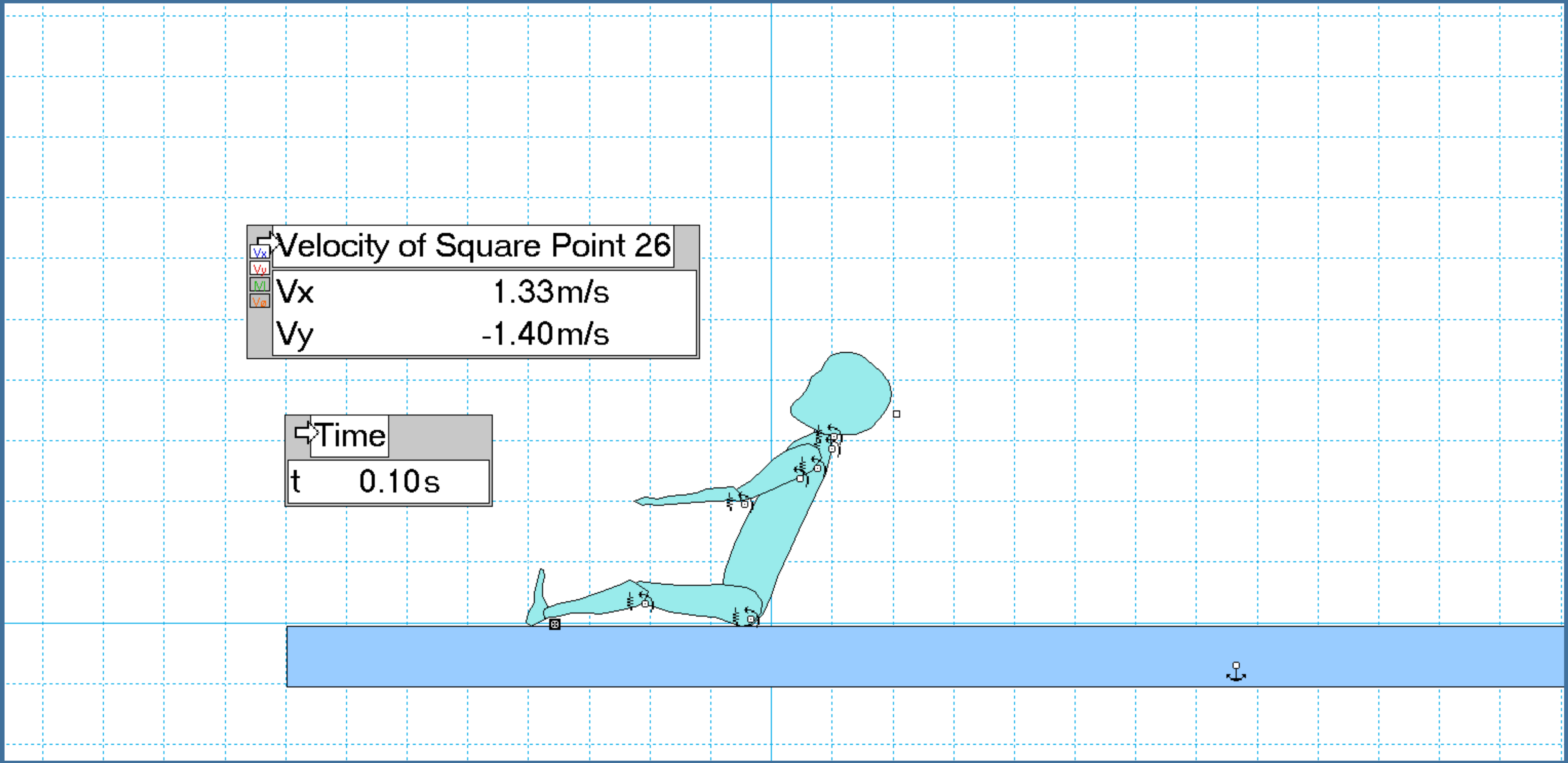
Standing up

- The torque around the hips required to stand straight up from the **7** to **|** position depends on how quickly it can be accomplished. For a reasonable 1.0 s and the body distribution for an 18-month boy, trial and error computer simulations showed that a torque of magnitude 21.1*cos(1.57*t) N-m around the hips worked well. The same torque was then applied to the model in a seated position to supplement gravity until impact at 0.21 s.

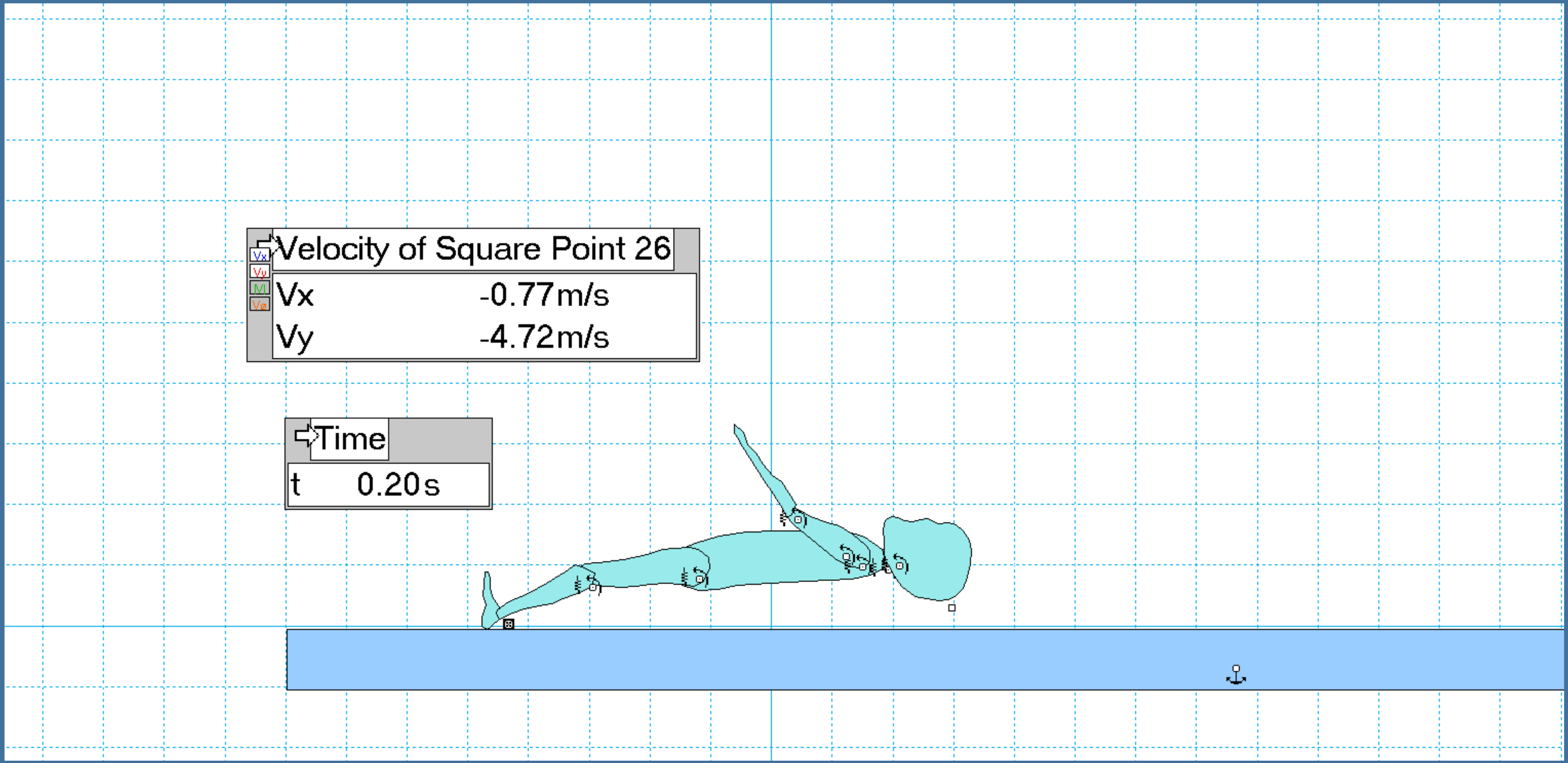
First-order approximations

- It is well known from work-energy considerations that an object falling freely from rest through height *h* will achieve an impact velocity $v = \sqrt{2gh,}$ where gravitational acceleration $g =$ 9.8 m/s/s = 32 feet/s/s = 22 miles/h/s. Similarly, a thin rod of length *L* that topples over about a fixed axis at its base from a vertical to horizontal position will have an upper end vertical impact velocity $v = \sqrt{3gL}$. The impact velocity decreases for points lower on the rod but approximates the straight drop result for a position located 0.82 *L* above the base. This computer simulation extends the concept to more realistic body shapes and includes the increase from the mousetrap effect.


Velocity of Square Point 26
Vx -0.03m/s
Vy 0.02m/s
Time
t 0.00s
The reference point on the back of the head will drop about 0.4 m.



Velocity of Square Point 26
Vx 1.33m/s
Vy -1.40m/s
Time
t 0.10s

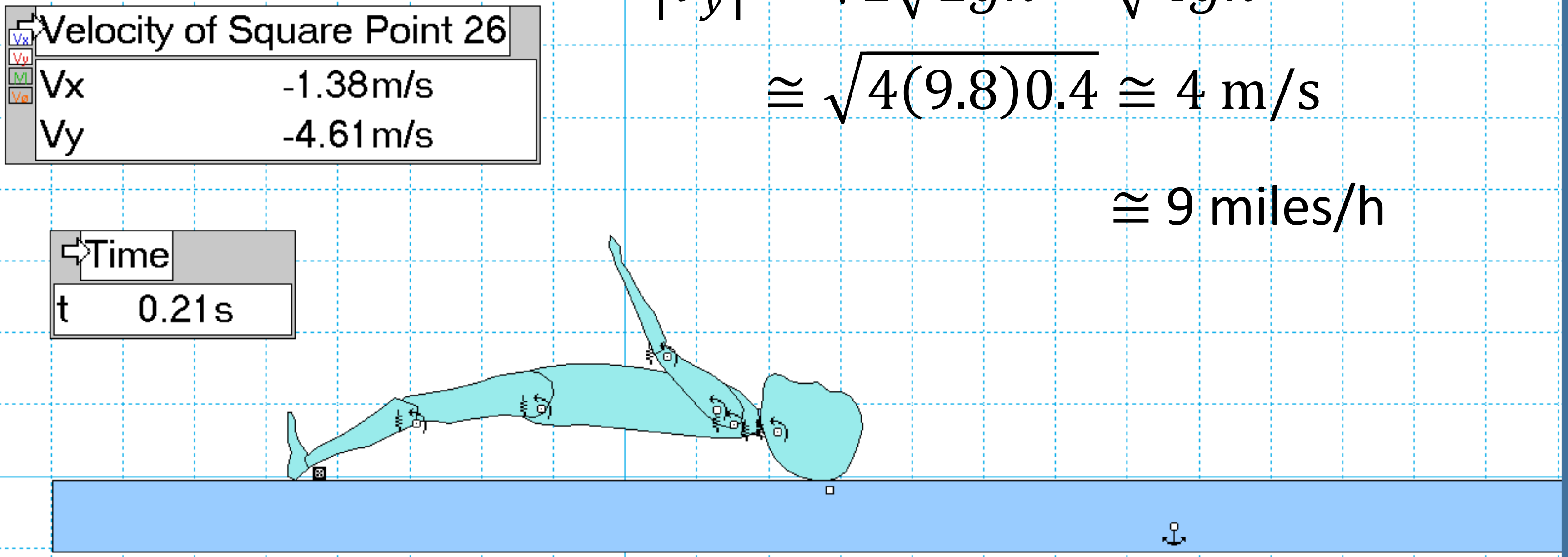

Velocity of Square Point 26
Vx -0.77m/s
Vy -4.72m/s
Time
t 0.20s

Impact velocity exceeds projected approximation:

$$|v_y| \cong \sqrt{2}\sqrt{2gh} \cong \sqrt{4gh}$$

$$\cong \sqrt{4(9.8)0.4} \cong 4\ \mathrm{m/s}$$

$\cong$ 9 miles/h



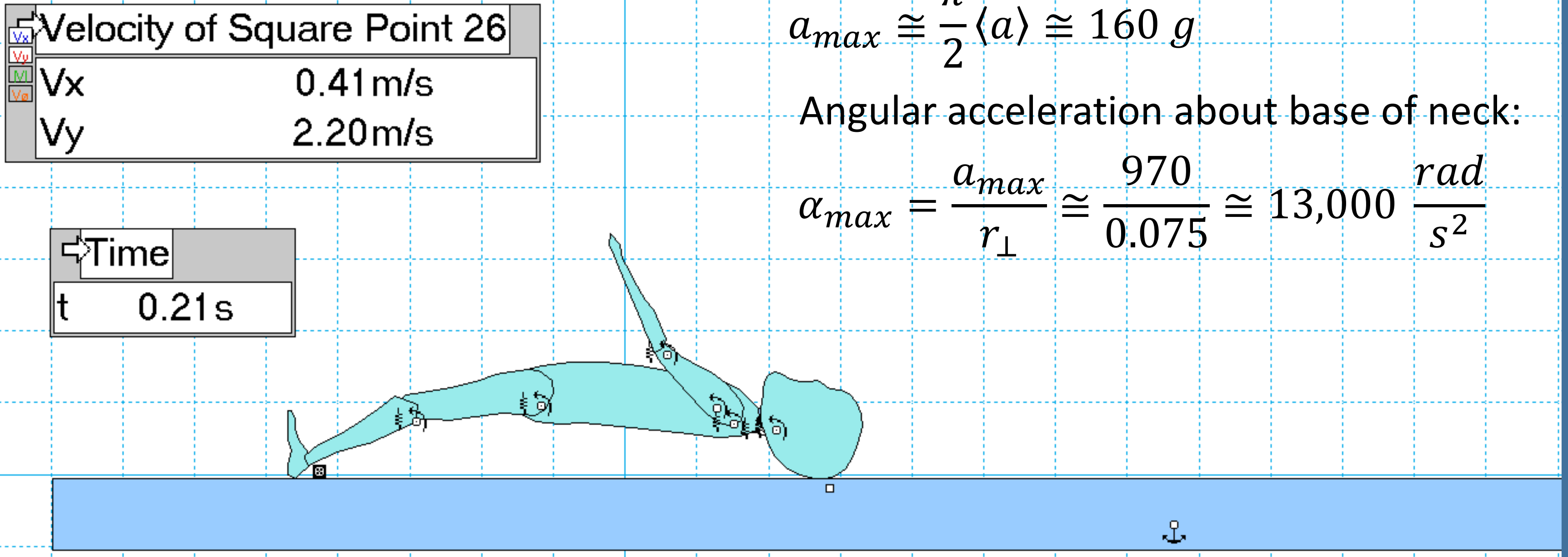
$$\langle a \rangle = \frac{\Delta v}{\Delta t} \cong \frac{(2.2 - (-4.6))}{0.007} \cong 970\ \frac{m}{s^2} \cong 99\ g$$

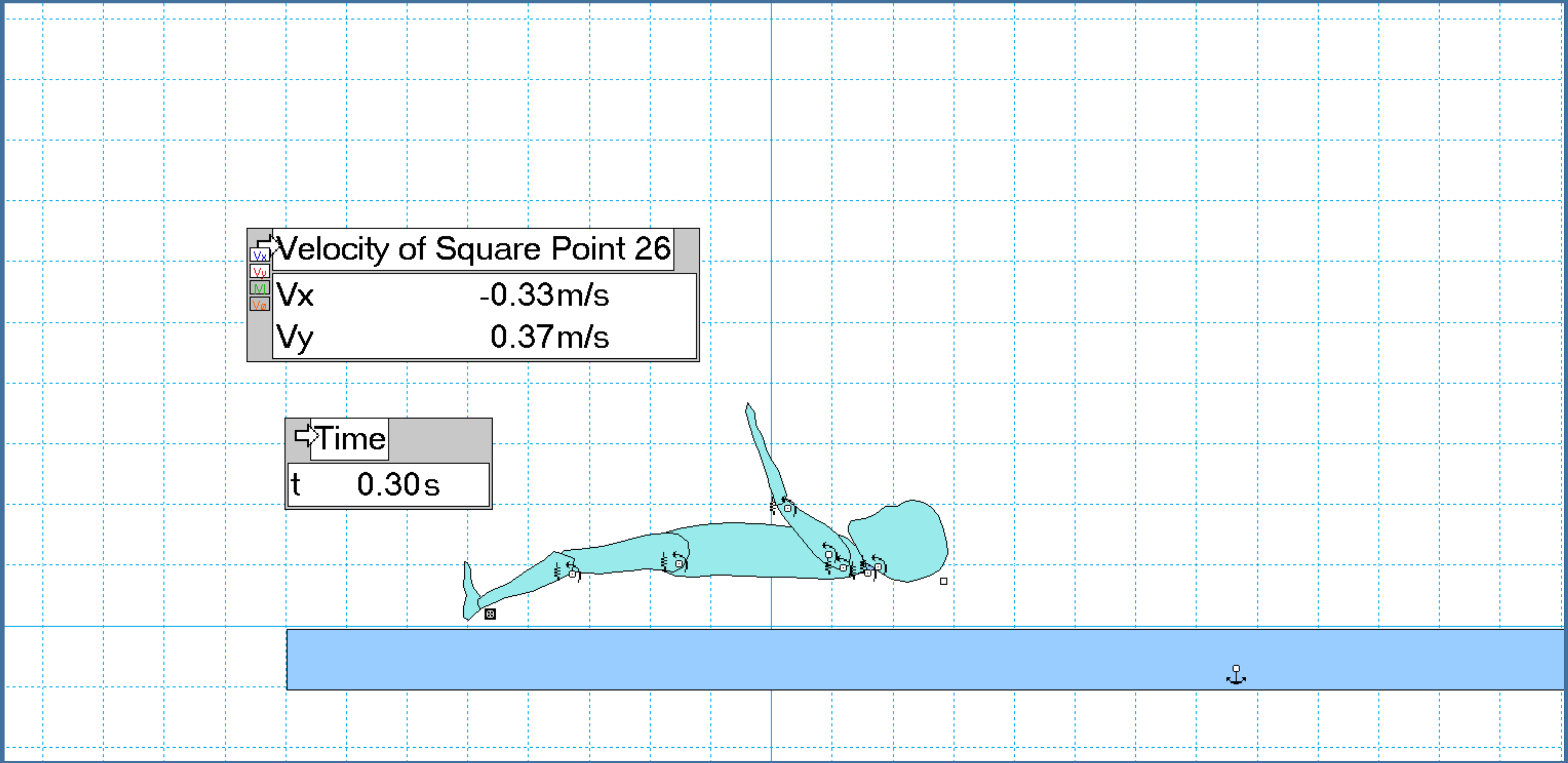
Half-sine force approximation:

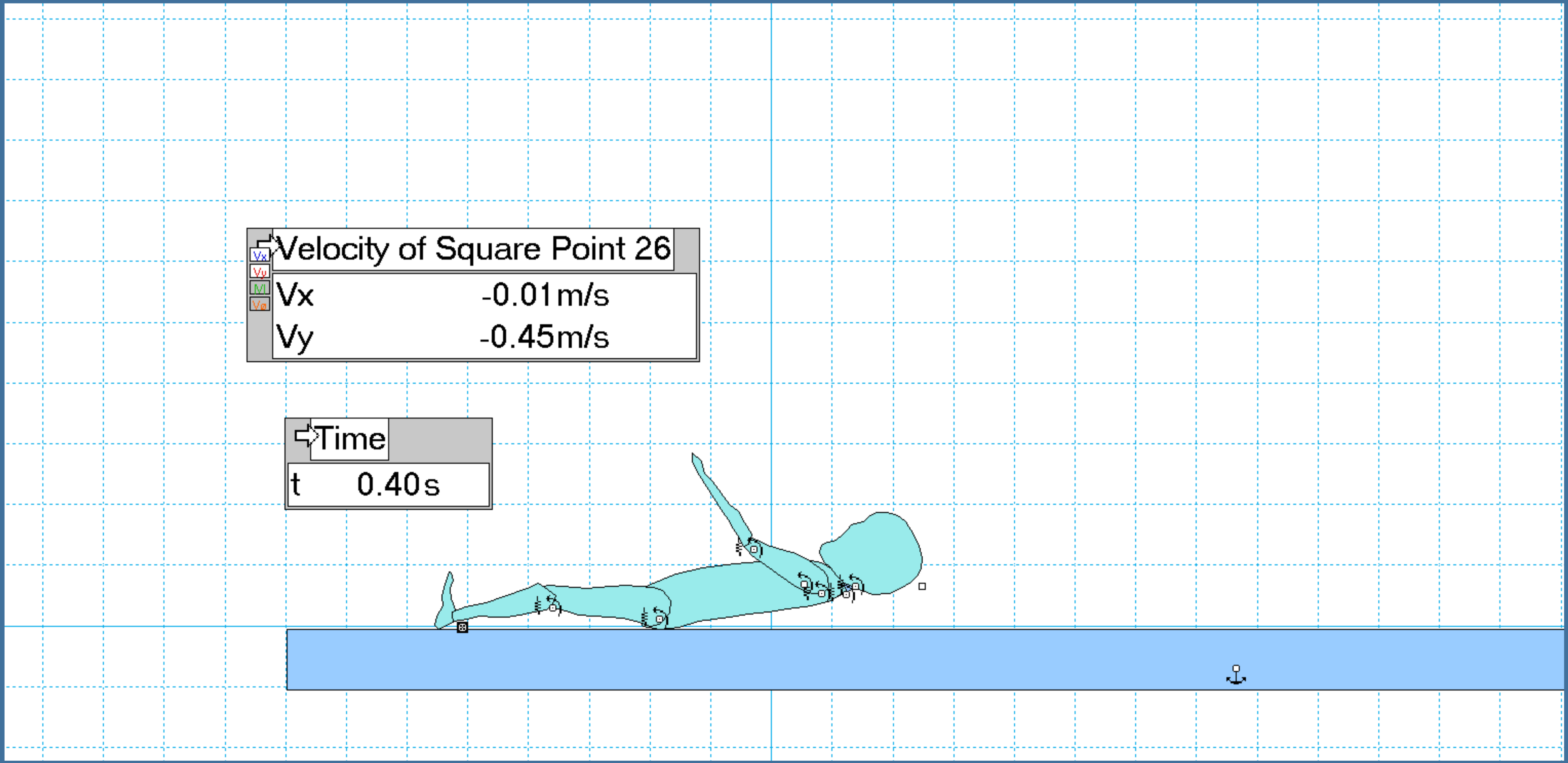
$$a_{max} \cong \frac{\pi}{2} \langle a \rangle \cong 160\ g$$

Angular acceleration about base of neck:

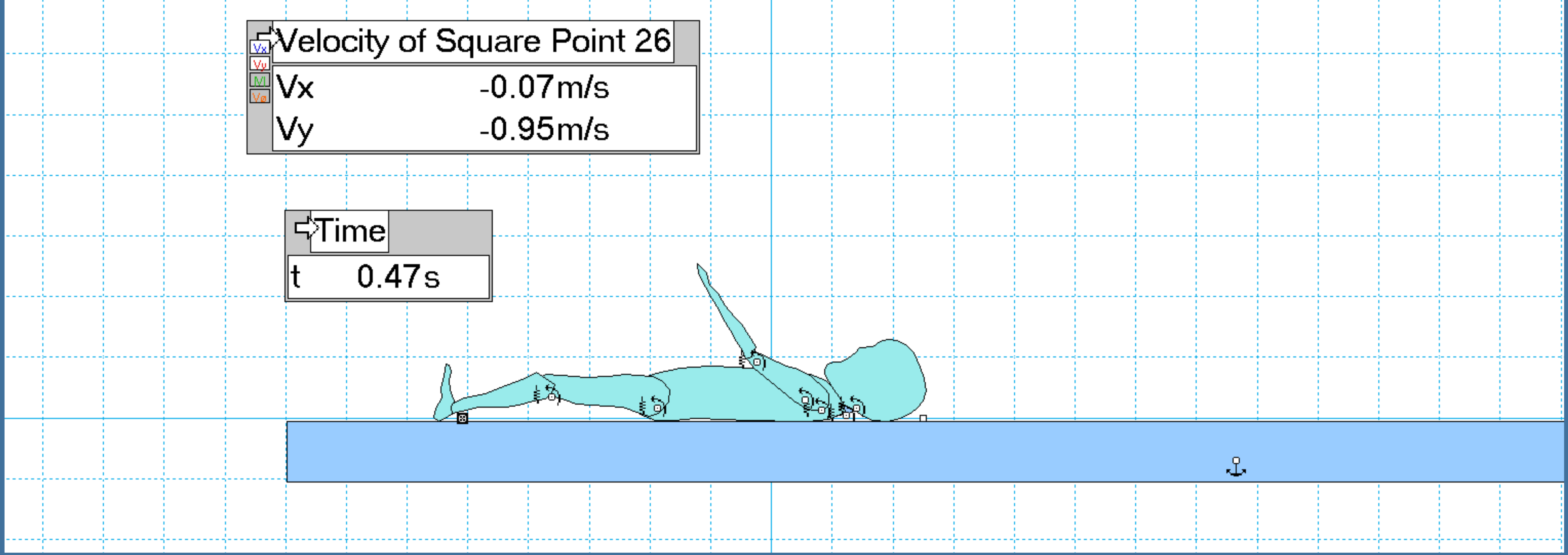
$$\alpha_{max} = \frac{a_{max}}{r_\perp} \cong \frac{970}{0.075} \cong 13{,}000\ \frac{rad}{s^2}$$




Velocity of Square Point 26
Vx -0.33m/s
Vy 0.37m/s
Time
t 0.30s


Velocity of Square Point 26
Vx -0.01 m/s
Vy -0.45 m/s
Time
t 0.40 s

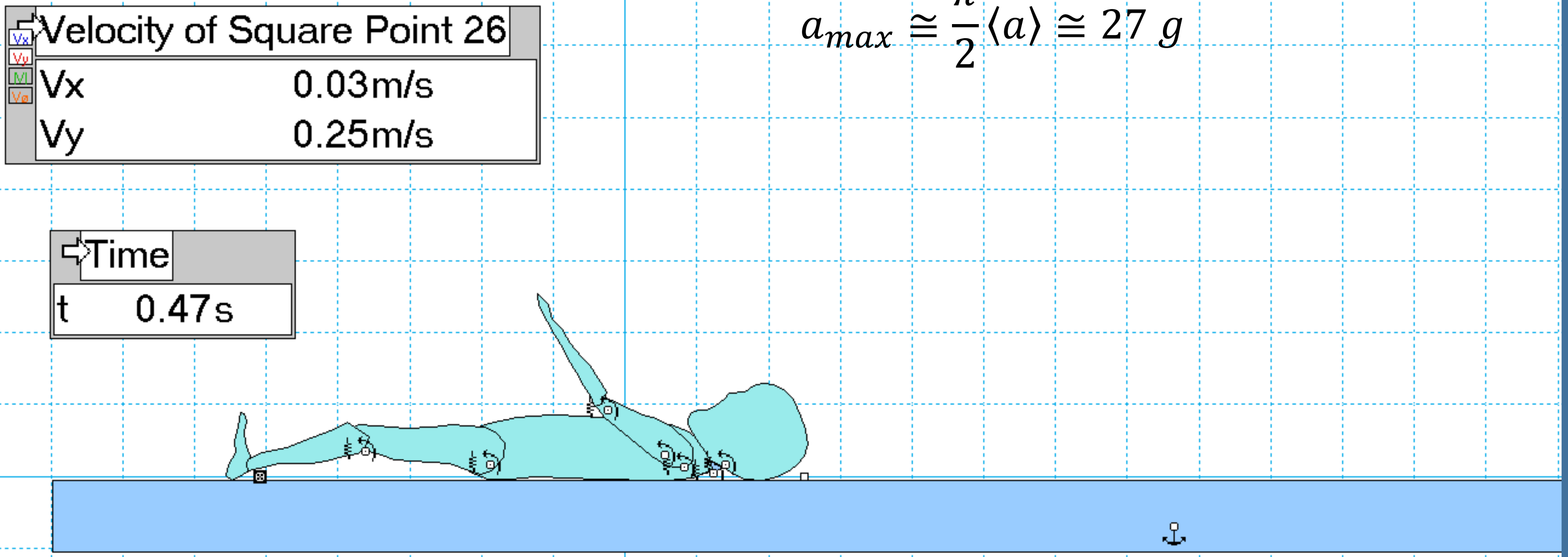
Second impact due to free-fall from rebound height

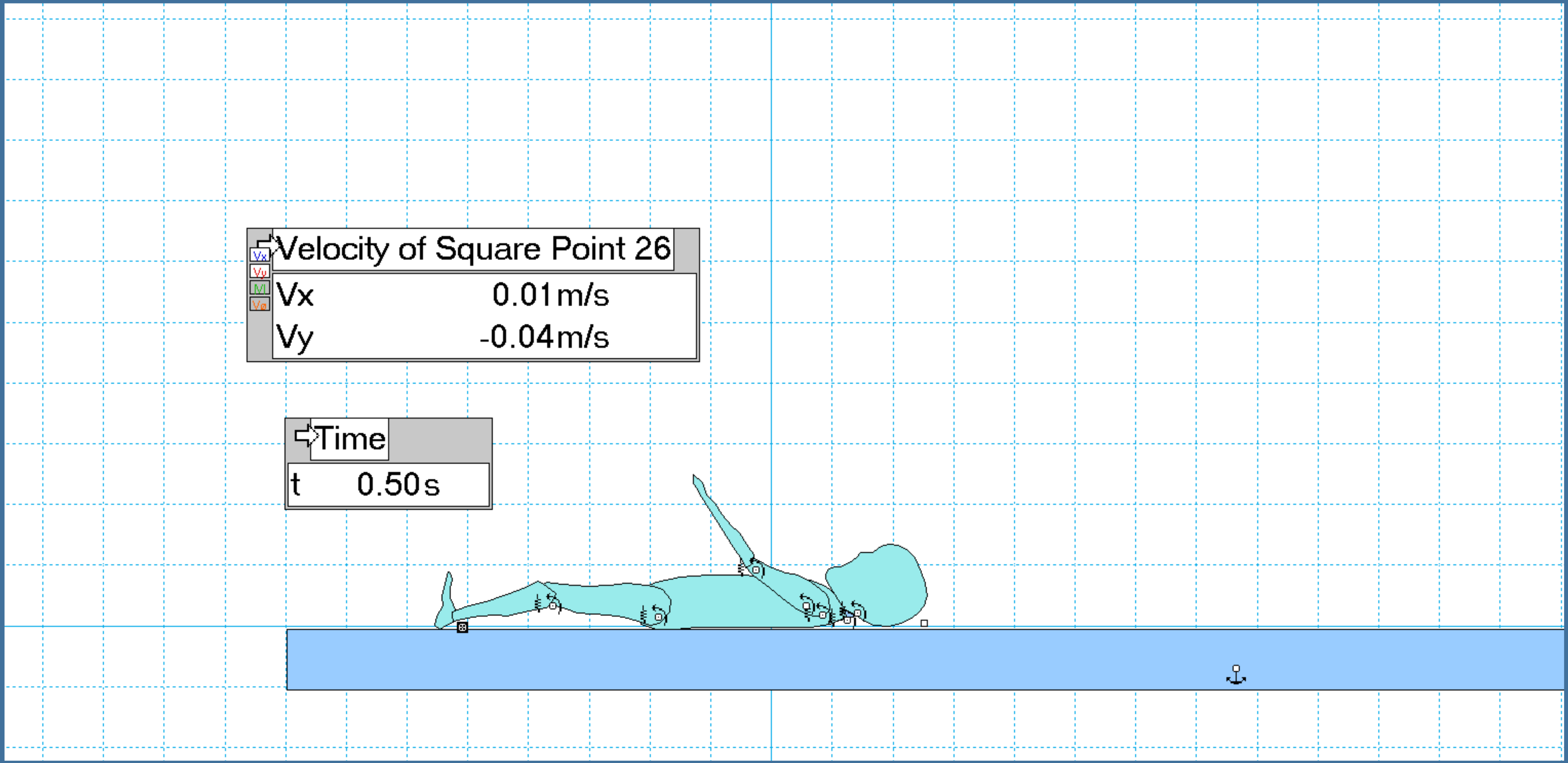


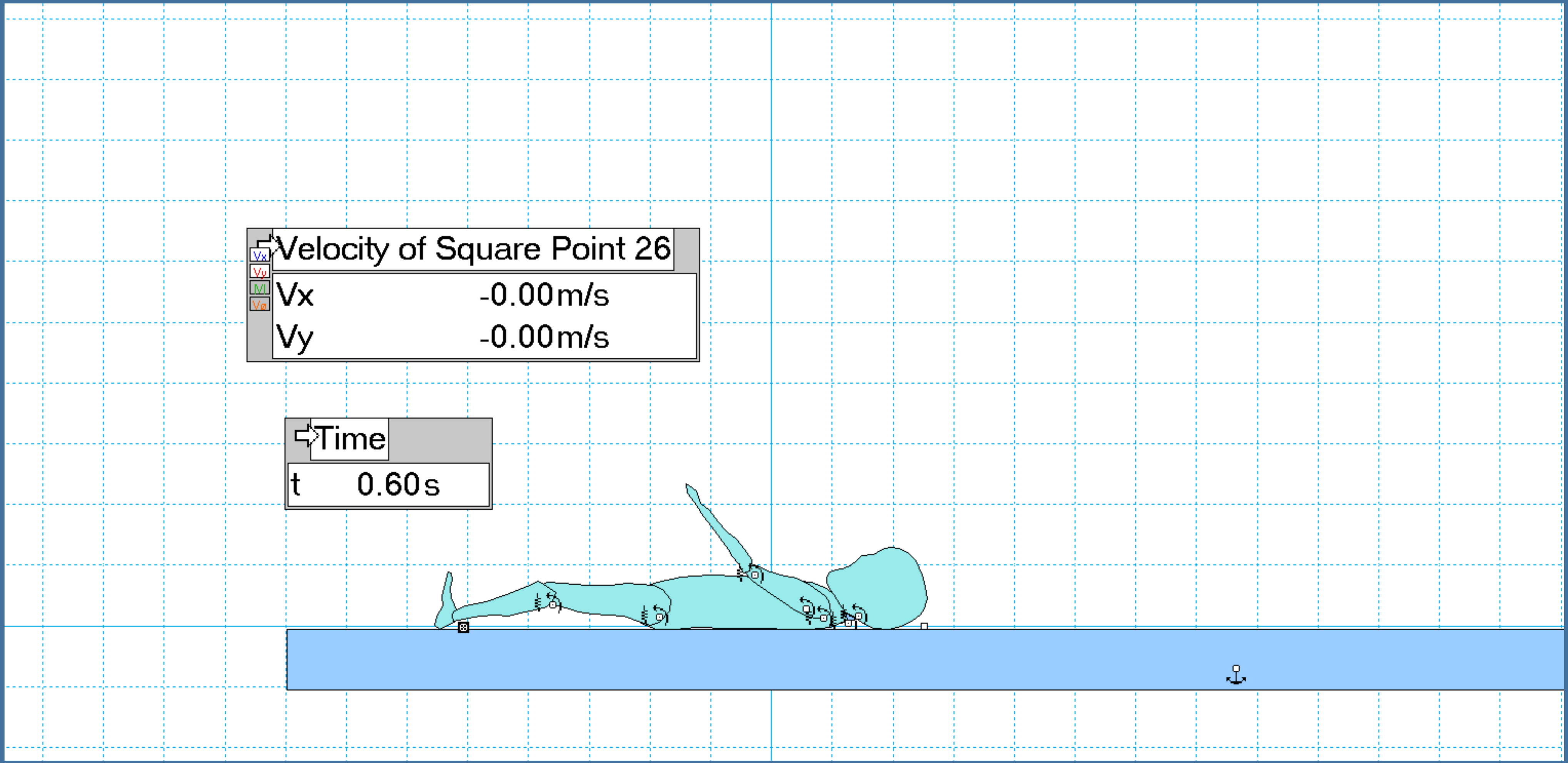
$$\langle a \rangle = \frac{\Delta v}{\Delta t} \cong \frac{(0.25 - (-0.95))}{0.007} \cong 170\ \frac{m}{s^2} \cong 17\ g$$

Half-sine force approximation:

$$a_{max} \cong \frac{\pi}{2} \langle a \rangle \cong 27\ g$$




Velocity of Square Point 26
Vx 0.01 m/s
Vy -0.04 m/s
Time
t 0.50 s


Velocity of Square Point 26
Vx -0.00 m/s
Vy -0.00 m/s
Time
t 0.60 s

Discussion

- The lack of a skull fracture suggests impact near the center of the skull where the occipital is significantly thicker.
- First impact produced accelerations more than 10 times greater than can be inflicted by shaking alone.
- Second impact still twice as much as from shaking alone.