A car travelling at 85 km/hr strikes a tree. The front end of the car compresses, and the driver comes to rest after traveling 0.80m. What was the average acceleration of the driver during the collision? Express the answer in terms of g's.

The dotted line shows the final position of the rear bumper. The solid line indicates position X = 0 m of rear bumper at the moment the car touched the tree.

\[ X_0 = 0 \text{ m} \]
\[ X = 0.80 \text{ m} \]
\[ V_o = 85 \text{ km/hr} \left[ \frac{1000 \text{ m}}{1 \text{ km}} \right] \left[ \frac{1 \text{ hr}}{3600 \text{ s}} \right] \]
\[ = 23.6 \text{ m/s} \]
\[ \sqrt{v} = 0 \text{ m/s} \]

\[ \alpha = ? \]
\[ + = \]

\[ \Delta v^2 = V_o^2 + 2 \alpha (x - x_o) \]
\[ \Delta v^2 = (23.6 \text{ m/s})^2 \pm 2 \alpha (0 \text{ m} - 0 \text{ m}) \]
\[ \alpha = -348 \text{ m/s}^2 = -35.5 \text{ g} \]
Determine the stopping distances for a car with an initial speed of 91 Km/h and human reaction time of 2.0s for the following acceleration:

a) \(a = -4.00 \text{ m/s}^2\)

b) \(a = -8.00 \text{ m/s}^2\)

\[x_0, x_1, x_2\]

\(x_0\) is the position of the car at the moment the 2.0s reaction time begins.

\(x_1\) is the position of the car at the end of the 2.0s reaction time. The brakes are finally applied at \(x_1\), and the car finally stops at \(x_2\).

\[x_0 = 0\]

\[x_1\]

\[x_2 = \]

\[v_0 = 91 \text{ Km/h} \left[ \frac{1000 \text{ m}}{1 \text{ km}} \right] \left[ \frac{1 \text{ h}}{3600 \text{ s}} \right] = 25.3 \text{ m/s}\]

\[v_f = 25.3 \text{ m/s} \text{ (since this is where the brakes are finally applied)}\]

\[v_2 = 0 \text{ m/s}\]
\[ x_1 = x_0 + v_0 t + \frac{1}{2} a t^2 \quad a = 0\ m/s^2 \text{ between } x_0 \text{ and } x_1 \]

\[ x_1 = 50.6\ m \]

\[ v_2^2 = v_1^2 + 2a(x_2 - x_1) \]

\[ (0\ m/s)^2 = (25.3\ m/s)^2 + 2(-4.90\ m/s^2)(x_2 - 50.6\ m) \]

\[ x_2 = 131\ m \]

\[ v_2^2 = v_1^2 + 2a(x_2 - x_1) \]

\[ (0\ m/s)^2 = (25.3\ m/s)^2 + 2(-8.00\ m/s^2)(x_2 - 50.6\ m) \]

\[ x_2 = 90.6\ m \]
A stone is dropped from the top of a cliff. It hits the ground below after 3.70s. How high is the cliff?

\[ x = x_0 + v_0 t + \frac{1}{2} a t^2 \]

Given:
- \( x = 0 \) (ground level)
- \( v_0 = 0 \) (initial velocity)
- \( a = -9.80 \text{ m/s}^2 \) (acceleration due to gravity)
- \( t = 3.70 \text{ s} \)

\[ 0 = x_0 + 0 \cdot (3.70) + \frac{1}{2} (-9.80) (3.70)^2 \]

Solving for \( x_0 \):
\[ x_0 = \frac{1}{2} (-9.80) (3.70)^2 \]

\[ x_0 = 67.1 \text{ m} \]
If a car rolls gently \((v_0 = 0)\) off a vertical cliff, how long does it take to reach 83 km/h?

\[ x = \]
\[ v_0 = 0 \text{ m/s}, \]
\[ v = \frac{83 \text{ km}}{3.6 \text{ m/s}} = -23.1 \text{ m/s} \]
\[ a = -9.80 \text{ m/s}^2 \]
\[ t = ? \]

\[ v = v_0 + at \]
\[ -23.1 \text{ m/s} = 0 \text{ m/s} + (-9.80 \text{ m/s}^2) \]
\[ t = 2.35 \text{ s} \]
Estimate how long it took King Kong to fall straight down from the top of a 250 m high building.

Estimate his velocity just before landing.

\[ x = x_0 + V_0 t + \frac{1}{2} a t^2 \]

\[ 0 = 250 \text{ m} + (0 \text{ m/s}) t + \frac{1}{2} (-9.80 \text{ m/s}^2) t^2 \]

\[ t = 7.14 \text{ s} \]

\[ v = v_0 + at \]

\[ v = 0 \text{ m/s} + (-9.80 \text{ m/s}^2) (7.14 \text{ s}) \]

\[ v = -70.0 \text{ m/s} \] (downward)
A baseball is hit nearly straight into the air with a speed of 41 m/s.

a) How high does it go?

b) How long is it in the air?

\[ x_1 = ? \quad x_0 = 0 \text{m} \]
\[ x_1 = ? \]
\[ x_0 = 0 \text{m} \]
\[ v_0 = 41.0 \text{ m/s} \]
\[ v_1 = 0 \text{ m/s} \]
\[ v_2 = \]
\[ a = -9.80 \text{ m/s}^2 \]
\[ t_2 = ? \]

\[ v_1^2 = v_0^2 + 2a(x_1 - x_0) \]
\[ (0\text{m/s})^2 = (41.0\text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(x_1 - 0\text{m}) \]
\[ x_1 = 85.8\text{m} \]

b) \[ x_2 = x_0 + v_0 \cdot t + \frac{1}{2}a \cdot t^2 \]
\[ 0\text{m} = 0\text{m} + (410\text{m/s}) \cdot t + \frac{1}{2}(-9.80 \text{ m/s}^2) \cdot t^2 \]
\[ t = 8.37\text{s} \]
A helicopter is ascending vertically with a speed of 1.50 m/s. At a height of 110 m above the earth, a package is dropped from a window. How much time does it take for the package to reach the ground?

\[ x_0 = 110 \text{ m} \]
\[ v_0 = 1.50 \text{ m/s} \]
\[ a = -9.80 \text{ m/s}^2 \]

\[ x = \frac{1}{2} at^2 \]
\[ 0 = 110 + (1.50t) + \frac{1}{2} (-9.80) t^2 \]

\[ t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]
\[ t = \frac{-1.50 \pm \sqrt{(1.50)^2 - 4(-9.80)(110)}}{2(-9.80)} \]
\[ t = 4.89 \text{ s} \text{ or } -4.50 \text{ s} \]
A rock is dropped from a sea cliff. The sound of it striking the water is heard 6.7 s later. If the speed of sound is 340 m/s, how high is the cliff?

\[ V_0 = 0 \text{ m/s} \]
\[ x_0 = ? \]
\[ x_0 = 0 \text{ m} \]
\[ V = ? \]
\[ a = -9.8 \text{ m/s}^2 \]
\[ t = 6.7 \text{ s} \]

The 6.7 s is not the time for the rock to fall. It is longer than the fall time by the time it took for the sound to travel up. So

\[ t_{\text{tot}} = t_{\text{sound}} + t_{\text{drop}} \]
\[ 6.7 \text{ s} = \frac{x_0}{340 \text{ m/s}} + t_{\text{drop}} \]
\[ t_{\text{drop}} = 6.7 \text{ s} - \frac{x_0}{340 \text{ m/s}} \]

Then for the rock

\[ x = x_0 + v_0 \cdot t_{\text{drop}} + \frac{1}{2} a \cdot t_{\text{drop}}^2 \]

\[ 0 = x_0 + (0 \text{ m/s}) \cdot t_{\text{drop}} + \frac{1}{2} (-9.8 \text{ m/s}^2) \cdot \left(6.7 \text{ s} - \frac{x_0}{340 \text{ m/s}}\right)^2 \]

\[ x_0 = 125.2 \text{ m} \]
A baseball is seen to pass upward by a window 20 m above the street with a vertical speed of 8 m/s. The ball was thrown from the street:

a) What was its initial speed?
b) What altitude does it reach?
c) How long after it was thrown did it pass the window?

\[ V^2 = V_0^2 + 2a(x-x_0) \]
\[ (8.00 \text{ m/s})^2 = V_0^2 + 2(-9.80 \text{ m/s}^2)(20.0 \text{ m} - 0 \text{ m}) \]
\[ V_0 = 21.4 \text{ m/s} \]

b) \[ V^2 = V_0^2 + 2a(x-x_0) \]
\[ (0 \text{ m})^2 = (21.4 \text{ m/s})^2 + 2(-9.80 \text{ m/s}^2)(x_{\text{max}} - 0 \text{ m}) \]
\[ x_{\text{max}} = 23.4 \text{ m} \]

c) \[ V = V_0 + at \]
\[ 8.00 \text{ m/s} = 21.4 \text{ m/s} + (-9.80 \text{ m/s}^2)t \]
\[ t = 1.26 \text{ s} \]
A stone is thrown vertically upwards with a speed of 12.5 m/s from the edge of a cliff 67.0 m high.

a) How much later does it reach the bottom of the cliff?

b) What is the speed just before hitting?

c) What total distance did it travel?

\[ X = 67.0 \text{ m} \]

\[ V_0 = 12.5 \text{ m/s} \]

\[ \ddot{a} = -9.80 \text{ m/s}^2 \]

\[ t = ? \]

\[ a) \quad X = X_0 + V_0 t + \frac{1}{2} a t^2 \]

\[ 0 = 67.0 + (12.5t) + \frac{1}{2} (-9.80) t^2 \]

\[ t = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

\[ t = \frac{-12.5 \pm \sqrt{(12.5)^2 - 4(-9.80)(67.0)}}{2(-9.80)} \]

\[ t = 5.18 \text{ s} \]

\[ V = V_0 + a t \]

\[ V = 12.5 \text{ m/s} + (-9.80 \text{ m/s}^2)(5.18) \]

\[ V = -38.3 \text{ m/s} \]
\[ v^2 = v_0^2 + 2a(x-x_0) \]
\[ (0m/s)^2 = (12.5m/s)^2 + 2(-9.80m/s^2)(x_{\text{max}} - 670m) \]
\[ x_{\text{max}} = 75.0m \]

\[ \text{total distance} = 75.0m + (75.0m + 670m) \]
\[ \boxed{830m} \]