“And in 1999, We Come to Super Bowl XXXIII Held in Miami, Florida...” (50,000 points)

1.) This is based on data from the Nike®-Budweiser®-Apple™-www.nfl.com-Super Bowl XXXIII®. With five minutes to go in the 2nd Quarter, Bronco QB #7 John Elway drops back and throws a pass that covers 50 yards (45.7 m) in 3.56 seconds, when the receiver, #80 Rod Smith, then runs with the ball another 40 yards (36.6 m) in 4.11 seconds for a touchdown. What is the average speed of the football?

\[
\frac{d}{t} = \frac{45.7\text{m} + 36.6\text{m}}{3.56\text{sec} + 4.11\text{sec}} = \frac{82.3\text{m}}{7.67\text{sec}} = 10.73\text{m/s}
\]

(b) Rod Smith, goes from rest to 8.91 m/s in a distance of 2.00 meters. What is the average acceleration of the runner?

\[
\frac{v^2 - 0^2}{2a} = \frac{(8.91\text{m/s})^2}{2(2.00\text{m})} = 19.85\text{m/s}^2
\]

(c) #5 Morton Anderson of the Atlanta Falcons kicked off the football after their “first blood” field goal at 9:24 in the 1st quarter. The ball travels downfield 52 yards (47.5 m) in 5.85 sec. Neglecting air resistance, as usual, find \(v_y\) and \(v_{0y}\) when it lands again.

\[
v_y = 0 \quad \text{(To top of arc.)} \quad t = \frac{1}{2}(5.85s) = 2.925s
\]

\[
\begin{align*}
v_y &= v_{0y} - gt \\
0 &= v_{0y} - gt \\
v_y &= gt \\
v_y &= (9.81\text{m/s}^2)(2.925s) \\
&= +28.69\text{m/s}
\end{align*}
\]

\[
\begin{align*}
v_y &= -v_{0y} \quad \text{(For symmetrical jump.)} \\
v_y &= v_{0y} - gt \\
-v_{0y} &= v_{0y} - gt \\
-2v_{0y} &= -gt \\
v_{0y} &= \frac{gt}{2} = \frac{(9.81\text{m/s}^2)(5.85s)}{2} \\
&= +28.69\text{m/s}
\end{align*}
\]

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\begin{align*}
v_y &= -v_{0y} \quad \text{(For symmetrical jump.)} \\
v_y &= v_{0y} - gt \\
-2v_{0y} &= -gt \\
v_{0y} &= \frac{gt}{2} = \frac{(9.81\text{m/s}^2)(5.85s)}{2} \\
&= +28.69\text{m/s}
\end{align*}
\]

(d) How high does the football go? This can be solved without an answer to (c).

\[
y = y_0 + v_{0y}t - \frac{1}{2}gt^2
\]

\[
= v_{0y}t - \frac{1}{2}gt^2
\]

\[
= (28.69\text{m/s})(2.925s) - \frac{1}{2}(9.81\text{m/s}^2)(2.925s)^2
\]

\[
= 41.95\text{m}
\]

\[
h = \frac{v_{0y}^2 \sin^2 \theta}{2g} = \frac{(29.82\text{m/s})^2 \sin^2(74.2^\circ)}{2(9.81\text{m/s}^2)} = 41.96\text{m}
\]

(e) Find the initial velocity vector, \(\vec{v}_0\), of the football. Give the answer in Standard Form. If you did not get an answer to (c), use \(v_{0y} = 9.81\text{ m/s}\).

\[
v_{0x} = \frac{d}{t} = \frac{47.5\text{m}}{5.85s} = 8.120\text{m/s} \quad \text{;} \quad v_{0y} = 28.69\text{m/s}
\]

\[
v_0 = \sqrt{v_{0x}^2 + v_{0y}^2} = \sqrt{(8.120\text{m/s})^2 + (28.69\text{m/s})^2} = 29.82\text{m/s}
\]

\[
\theta = \tan^{-1}\left(\frac{v_{0y}}{v_{0x}}\right) = \tan^{-1}\left(\frac{28.69\text{m/s}}{8.120\text{m/s}}\right) = 74.2^\circ
\]

\[
\vec{v}_0 = 29.82\text{m/s} @ 74.2^\circ
\]
“You Have No Concept of the Power of Star Problems!” DARTH VADER (50,000 points)

2.) An object’s equation of motion is \( \frac{dx}{dt} = 6.00 \text{m/s} \), with \( v_0 = 6.00 \text{ m/s} \). All other constants are zero.

\( \Delta \) (a) Find the equation for the position of this object.

\[
x = \int \frac{dx}{dt} dt = \int \left[ (0.05000 \text{ m/s}^3) t^5 + 6.00 \text{m/s} \right] dt
\]

\[
= \frac{1}{6} (0.05000 \text{ m/s}^3) t^6 + (6.00 \text{m/s}) t + C ; \quad (C = x_0 = 0)
\]

\[
= (0.008333 \text{ m/s}^3) t^6 + (6.00 \text{m/s}) t
\]

\( \Delta \) (b) Find the equation for the speed of this object.

\[
v_s = \frac{dx}{dt} = \int \frac{d^2 x}{dt^2} dt = \int \left[ (0.2500 \text{ m/s}^4) t^4 \right] dt
\]

\[
= \frac{1}{5} (0.2500 \text{ m/s}^4) t^5 + C ; \quad (C = v_0 = 6.00 \text{ m/s})
\]

\[
= (0.05000 \text{ m/s}^4) t^5 + 6.00 \text{m/s}
\]

\( \Delta \) (c) Find the equation for the acceleration of this object.

\[
a_s = \frac{d^2 x}{dt^2} ; \quad \frac{d^3 x}{dt^3} = +6.00 \text{ m/s}^4
\]

\[
d^2 x \quad \frac{dt^2}{dt^2} = \int \frac{d^2 x}{dt^2} dt = \int \left[ 6.00 \text{ m/s}^3 \right] dt
\]

\[
= (6.00 \text{ m/s}^3) t + C ; \quad (C = 0)
\]

\[
d^3 x \quad \frac{dt^3}{dt^3} = \int \frac{d^3 x}{dt^3} dt = \int \left[ (6.00 \text{ m/s}^4) t^2 \right] dt
\]

\[
= \frac{1}{2} (6.00 \text{ m/s}^4) t^3 + C ; \quad (C = j_0 = 0)
\]

\[
d^4 x \quad \frac{dt^4}{dt^4} = \int \frac{d^4 x}{dt^4} dt = \int \left[ \frac{1}{2} (6.00 \text{ m/s}^5) t^4 \right] dt
\]

\[
= \frac{1}{24} (6.00 \text{ m/s}^5) t^5 + C ; \quad (C = a_0 = 0)
\]

\[
a_s = (0.2500 \text{ m/s}^4) t^4
\]

\( \Delta \) (e) An object has its motion given as \( a(t) = (6.00 \text{m/s}^2) \). Find the second derivative of \( x \) with respect to time at time \( t = 1.00 \text{ sec} \).

\[
a = \frac{d^2 x}{dt^2}
\]

So \( a = \frac{d^2 x}{dt^2} = 6.00 \text{m/s}^2 \)

at \( t = 1.00 \text{ sec} \), still is \( 6.00 \text{m/s}^2 \)