

# Problem 1.15

[Difficulty: 5]

**1.15** For Problem 1.14, the initial horizontal speed of the sky diver is 70 m/s. As she falls, the  $k$  value for the vertical drag remains as before, but the value for horizontal motion is  $k = 0.05 \text{ N} \cdot \text{s/m}^2$ . Compute and plot the 2D trajectory of the sky diver.

**Given:** Data on sky diver:  $M = 70 \text{ kg}$   $k_{\text{vert}} = 0.25 \frac{\text{N} \cdot \text{s}^2}{\text{m}^2}$   $k_{\text{horiz}} = 0.05 \frac{\text{N} \cdot \text{s}^2}{\text{m}^2}$   $U_0 = 70 \frac{\text{m}}{\text{s}}$

**Find:** Plot of trajectory.

**Solution:** Use given data; integrate equation of motion by separating variables.

Treat the sky diver as a system; apply Newton's 2nd law in horizontal and vertical directions:

Vertical: Newton's 2nd law for the sky diver (mass  $M$ ) is (ignoring buoyancy effects):  $M \frac{dV}{dt} = M \cdot g - k_{\text{vert}} V^2$  (1)

For  $V(t)$  we need to integrate (1) with respect to  $t$ :

Separating variables and integrating:  $\int_0^V \frac{V}{\frac{M \cdot g}{k_{\text{vert}}} - V^2} dV = \int_0^t 1 dt$

so  $1 = \frac{1}{2} \sqrt{\frac{M}{k_{\text{vert}} g}} \ln \left( \frac{\sqrt{\frac{M \cdot g}{k_{\text{vert}}}} + V}{\sqrt{\frac{M \cdot g}{k_{\text{vert}}}} - V} \right)$

Rearranging:  $V(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \frac{\left( e^{\frac{2 \sqrt{\frac{k_{\text{vert}} g}{M}} t}} - 1 \right)}{\left( e^{\frac{2 \sqrt{\frac{k_{\text{vert}} g}{M}} t} + 1} \right)}$  so  $V(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \tanh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right)$

For  $y(t)$  we need to integrate again:  $\frac{dy}{dt} = V$  or  $y = \int V dt$

$y(t) = \int_0^t V(t) dt = \int_0^t \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \tanh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) dt = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \ln \left( \cosh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) \right)$

$y(t) = \sqrt{\frac{M \cdot g}{k_{\text{vert}}}} \ln \left( \cosh \left( \sqrt{\frac{k_{\text{vert}} g}{M}} t \right) \right)$

# Solutions Manual Fluid Mechanics Fox And Mcdonald

**Robert W. Fox, Alan T. McDonald**



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