

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

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

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

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

Introduction To Fluid Mechanics 8th Solution Manual

Camilla Rothe



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