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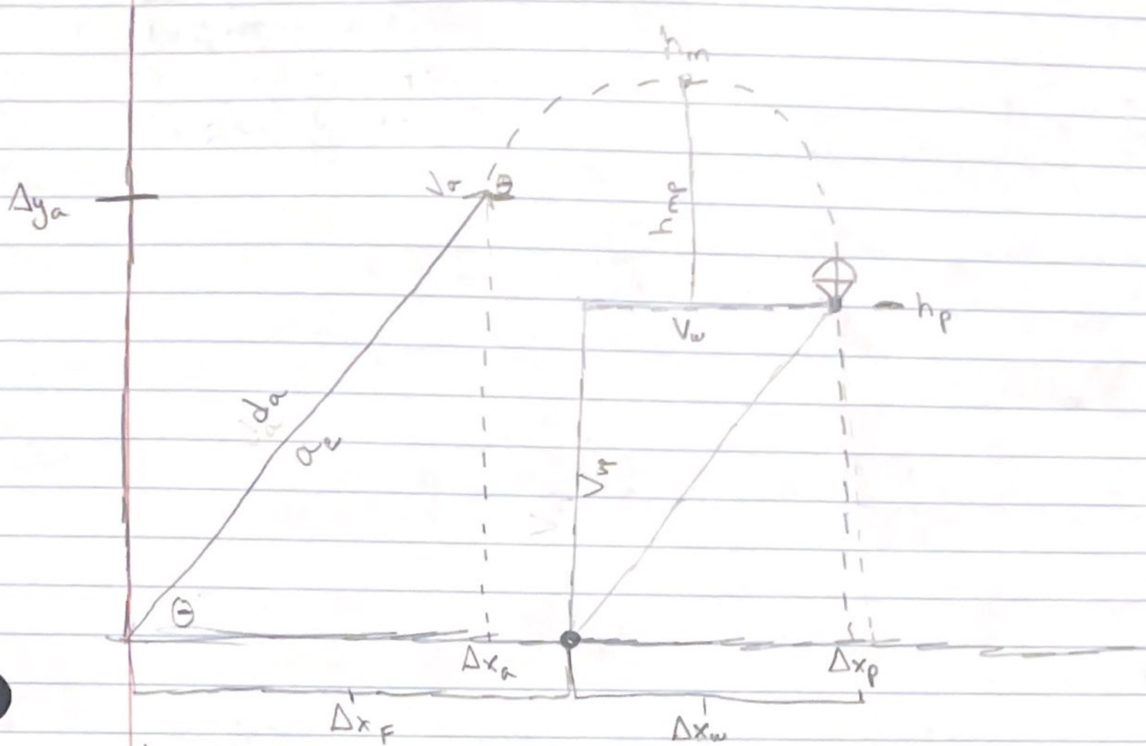
Multi-Step Rocket



Variables

Θ = Launch angle = 47° t_e = engine burn time = 8.7 sec a_e = engine acceleration = 5.2 m/s²
h_{mp} = Max height to parachute = 76 m V_{vp} = Vertical parachute velocity = 8 m/s
V_w = wind + parachute velocity = 17 m/s V_a = final velocity after acceleration = 45.24 m/s
d_a = distance after acceleration = 196.794 m Δy_a = height after acceleration = 143.926 m
h_m = max height = 199.777 m Δx_a = ground distance after acceleration = 134.213 m h_p = parachute height = 123.777 m
Δx_p = ground distance when parachute starts = 225.663 m t_p = time as projectile = 7.314 sec
t_f = time as its falling as parachute = 15.472 sec Δx_w = distance it goes from parachute to ground = -263.024
Δx_F = Displacement from start → finish = 96.85 m

Procedure

1 • Solving for the final velocity after acceleration (V_a). Use the no-Δx equation
- $V_a = V_0 + a_e t_e \rightarrow V_a = 0 + 5.2 \cdot 8.7 = \boxed{45.24 \text{ m/s}}$

2 • Solving for distance after acceleration (d_a). Use the no-final V equation
- $X = X_0 + V_0 t_e + \frac{1}{2} a_e t_e^2$, $\Delta x = d_a$, $d_a = V_0 t_e + \frac{1}{2} a_e t_e^2$
- $d_a = 0 + \frac{1}{2}(5.7)(8.7)^2 = \boxed{196.794}$

3. • Solving for height after acceleration (Δy_a). Use the sin theorems
- $\sin(\Theta) = \frac{\Delta y_a}{d_a} \rightarrow \sin(47) = \frac{\Delta y_a}{196.794}$, $\Delta y_a = \sin(47) \cdot 196.794 = \boxed{143.926 \text{ m}}$

4. Solving for displacement on the ground after acceleration (Δx_a). Use pythagorean theorem
   - $\Delta x_a^2 + \Delta y_a^2 = d_a^2$
   - $\Delta x_a^2 + 143.926^2 = 196.794^2$
   - $\Delta x_a^2 = 18013.185 \rightarrow \boxed{\Delta x_a = 134.213\text{ m}}$

5. Solving for max height (h_m), find V_{y_0} component of projectile path
   - $V_y = V_a \times \sin\theta \rightarrow V_y = 45.24 \cdot \sin 47 = \boxed{33.086\text{ m/s}}$

   Now, use the no-time kinematic equation to find h_m (Only use vertical components)
   - $V_f^2 = V_y^2 - 2gh$
   - $0 = 33.086^2 - 2(9.8)(h)$, $19.6h = 1094.683$, $h = 55.851\text{ m}$
   - $h_m = h + \Delta y_a$, $h_m = 55.851 + 143.926 = \boxed{199.777\text{ m}}$

6. Find the height when the parachute is deployed (h_p). Use simple arithmetic
   - $h_p = h_m - h_{mp}$, $h_p = 199.777 - 76 = \boxed{123.777\text{ m}}$

7. Find the displacement of the parachute from when it turns into a projectile (Δx_p). Use the no-final velocity equation and the the Δx equation.
   - $h_p = \Delta y_a + V_a \cdot \sin\theta \cdot t_p - 4.9t_p^2$
   - $123.777 = 143.926 + 45.24 \cdot \sin(47) \cdot t_p - 4.9t_p^2$
   - $-20.149 = 33.086t_p - 4.9t_p^2$, $\boxed{t_p = 7.314\text{ sec}}$
   - $\Delta x_p = V_a \cdot \cos(\theta) \cdot t_p$, $\Delta x_p = 45.24 \cdot \cos(47) \cdot 7.314 = \boxed{225.663\text{ m}}$

8. Find the displacement of the parachute to the ground (Δx_w). Use $\Delta y = Vt$ and $\Delta x = Vt$
   - First, do vertical fall. Find the time
     - $\Delta y = Vt \rightarrow h_p = V_{vp} \cdot t_f \rightarrow 123.777 = 8t_f$, $\boxed{t_f = 15.472\text{ sec}}$

   Now, plug t_f into horizontal fall. Find Δx_w
   - $\Delta x = Vt \rightarrow \Delta x_w = V_w \cdot t_f \rightarrow \Delta x_w = 17 \cdot 15.472 = \boxed{-263.024\text{ m}}$

9. Find the displacement of start to finish. Use logical arithmetic. (Δx_f)
   - $\Delta x_f = \Delta x_a + \Delta x_p + \Delta x_w$
   - $\Delta x_f = 134.213 + 225.663 - 263.024 = \boxed{96.852\text{ m}}$

$\Delta x_f = 96.85$ meters East