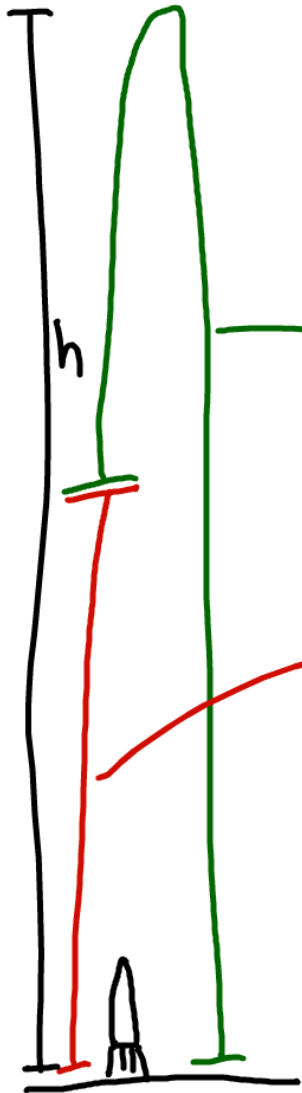


# 2-Stage Rocket

Level: High school physics, AP physics

Q) A toy rocket accelerates at a rate of  $20 \text{ m/s}^2$  for 10 seconds.

- 1) Find the maximum height of the rocket?
- 2) Find the total time that the rocket is in the air?



$$a = -9.8 \text{ m/s}^2 \approx -10 \text{ m/s}^2$$

$$a = 20 \text{ m/s}^2$$
$$t = 10 \text{ s}$$

# Review of 1D Kinematics

→  $a \rightarrow$  constant

→  $a, v, t, \Delta y, v_0 \rightarrow$  5 variables;  $\Delta y = y - y_0$

Big 5

Missing

1)  $\Delta y = \left( \frac{v_0 + v}{2} \right) t \longrightarrow a$

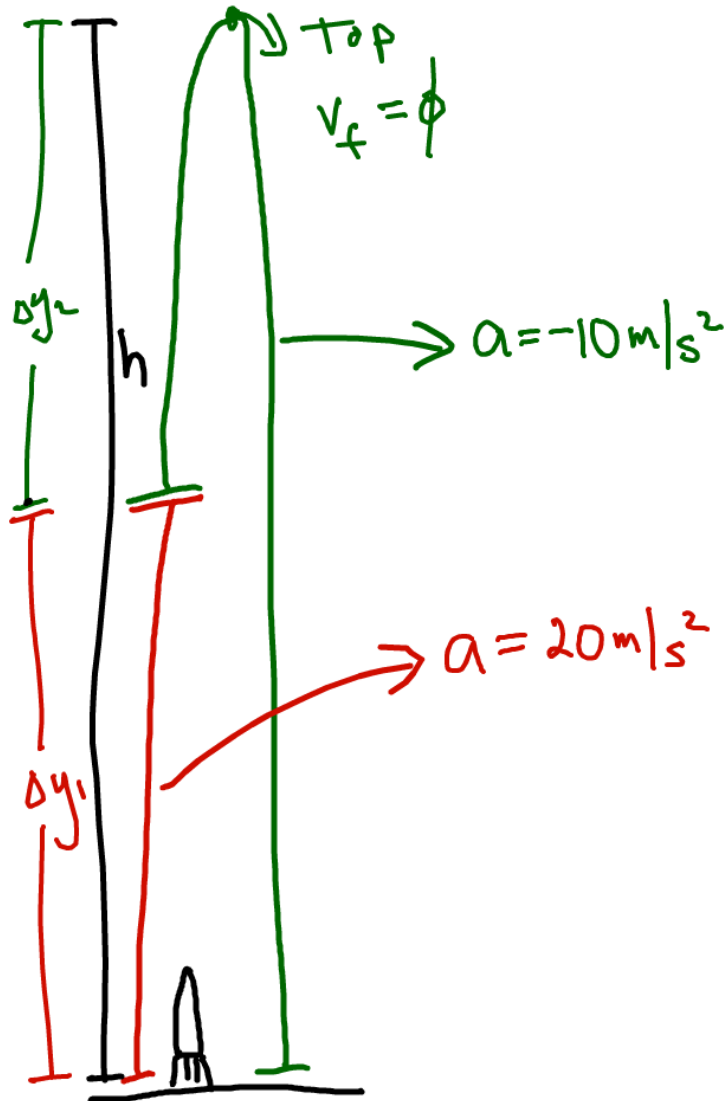
2)  $v = v_0 + at \longrightarrow \Delta y$

3)  $\Delta y = v_0 t + \frac{1}{2} at^2 \longrightarrow v$

4)  $\Delta y = vt - \frac{1}{2} at^2 \longrightarrow v_0$

5)  $v^2 = v_0^2 + 2a\Delta y \longrightarrow t$

# 2-Stage Rocket



$$\begin{aligned}
 h &= \Delta y_1 + \Delta y_2 \\
 &= 1000 + 2000 \\
 h &= 3000 \text{ m}
 \end{aligned}$$

## Part 1

$$a = 20 \text{ m/s}^2$$

$$\rightarrow t = 10 \text{ sec}$$

$$\Delta y_1 = v_0 t + \frac{1}{2} a t^2 = \frac{1}{2} (20) (10)^2 = 1000 \text{ m}$$

$$v = v_0 + a t = 20 \cdot 10 = 200 \text{ m/s}$$

## Part 2

$$a = -10 \text{ m/s}^2$$

$$t = ?$$

$$v_0 = 200 \text{ m/s}$$

$$\Delta y_2 = v_0 t + \frac{1}{2} a t^2$$

$$\begin{aligned}
 \Delta y_2 &= 200 \cdot 20 + \frac{1}{2} (-10) (20)^2 \\
 &= 4000 + (-2000) = 2000 \text{ m}
 \end{aligned}$$

$$\text{at top } v = 0$$

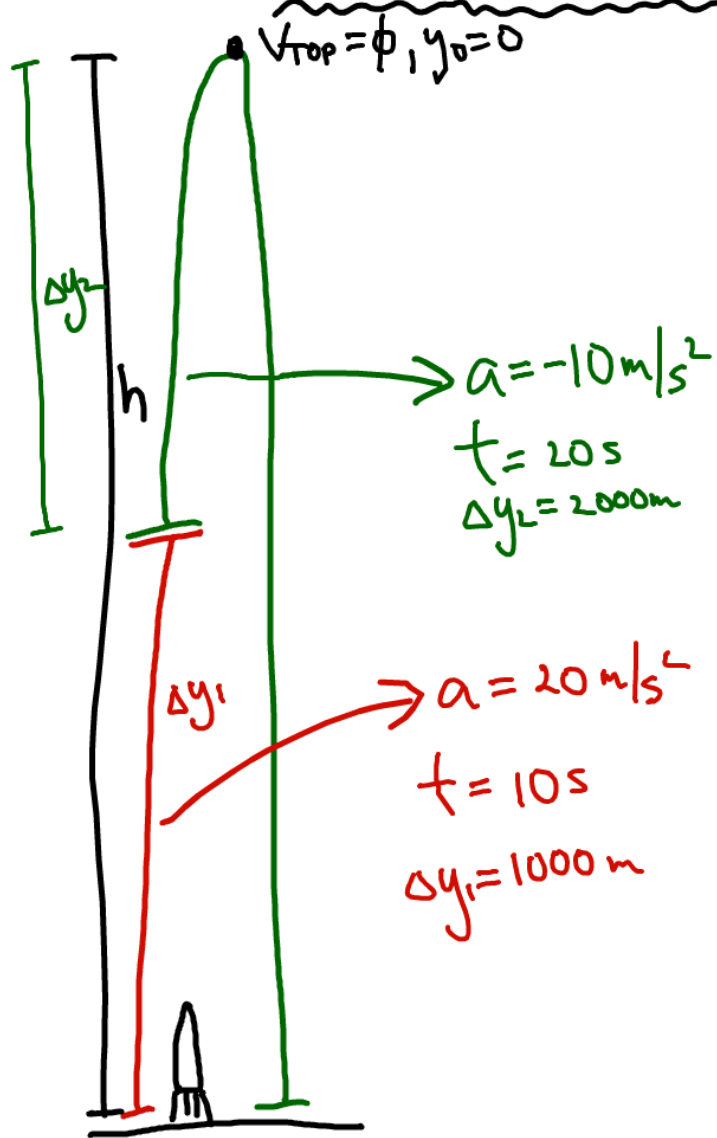
$$v = v_0 + a t$$

$$0 = v_0 + a t$$

$$t = \frac{-v_0}{a} = \frac{-200}{-10} = 20 \text{ sec}$$

$$t = 20 \text{ sec}$$

# 2-Stage Rocket



$$h = 3000 \text{ m.}$$

$$2) \text{ total flight time} = 10 + 20 + t_{\text{down}}$$

$$\Rightarrow a = -10 \text{ m/s}^2$$

$$v_0 = 0$$

$$\Delta y = v_0 t + \frac{1}{2} a t^2$$

$$y - y_0 = v_0 t + \frac{1}{2} a t^2 \Rightarrow -3000 - \phi = \frac{1}{2} (-10) t^2$$

$$t = \sqrt{\frac{2 \cdot 3000}{10}} = \sqrt{600} = 24.5 \text{ sec}$$

$$\text{total flight time} = 10 + 20 + 24.5$$
$$= 54.5 \text{ sec}$$

