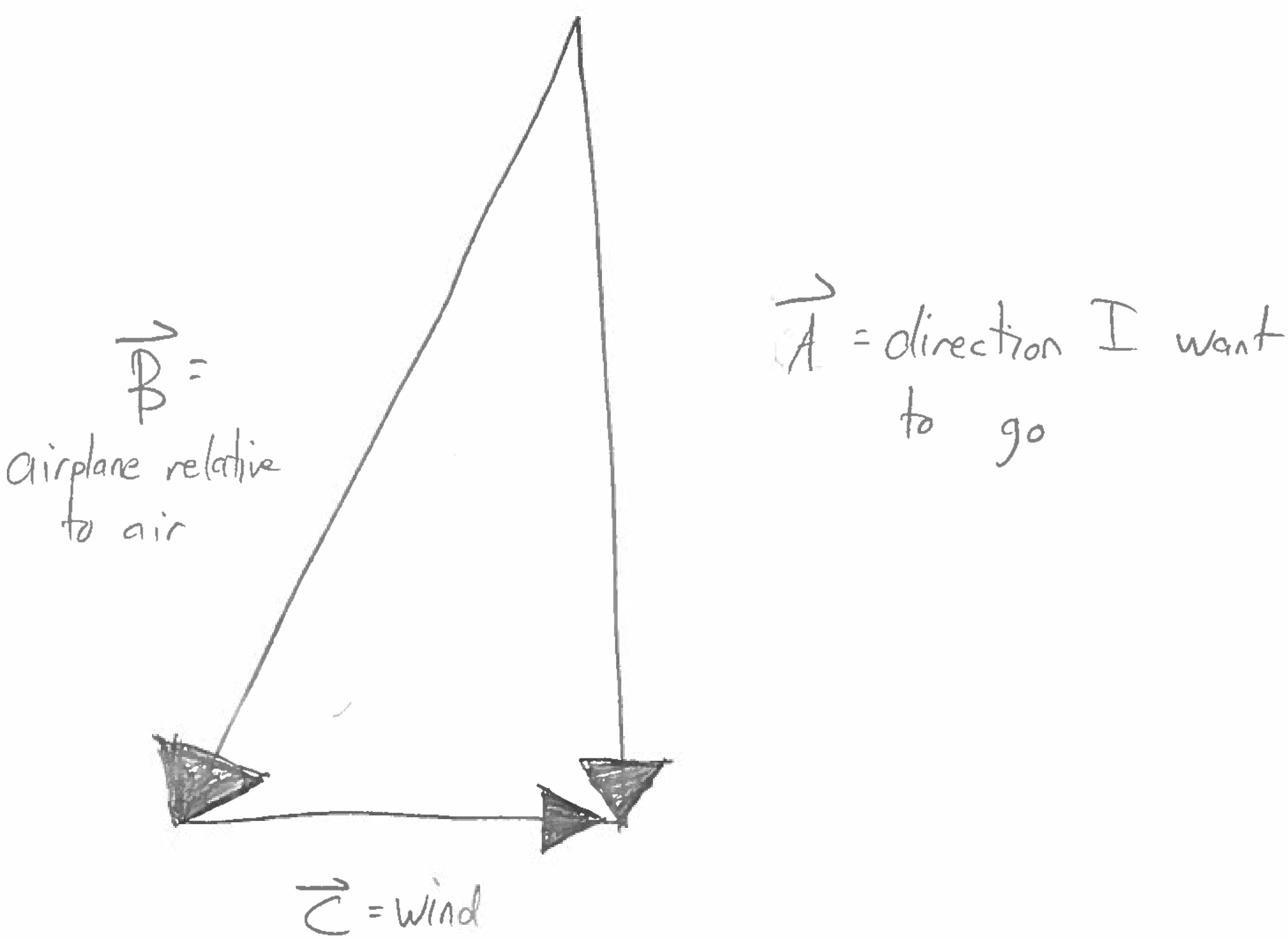
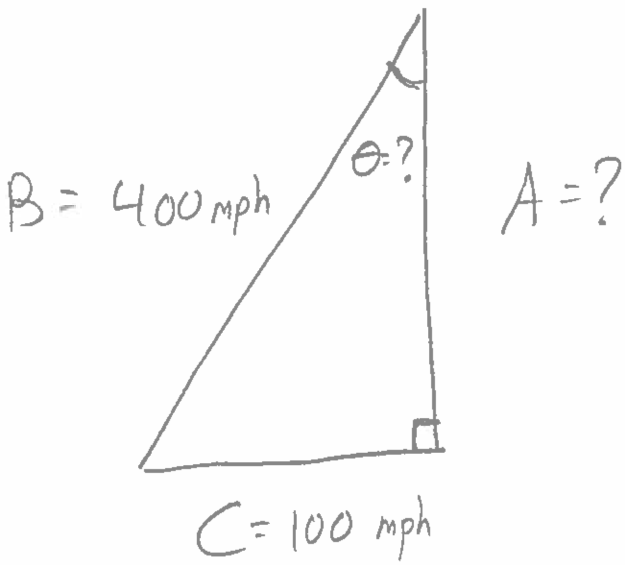
#1 c)




b) $\vec{B} + \vec{C} = \vec{A}$

a) I need to angle my plane southwest, so once the wind blows me back east, I am going south.

d) Now redraw this with numbers: | #1 cont.



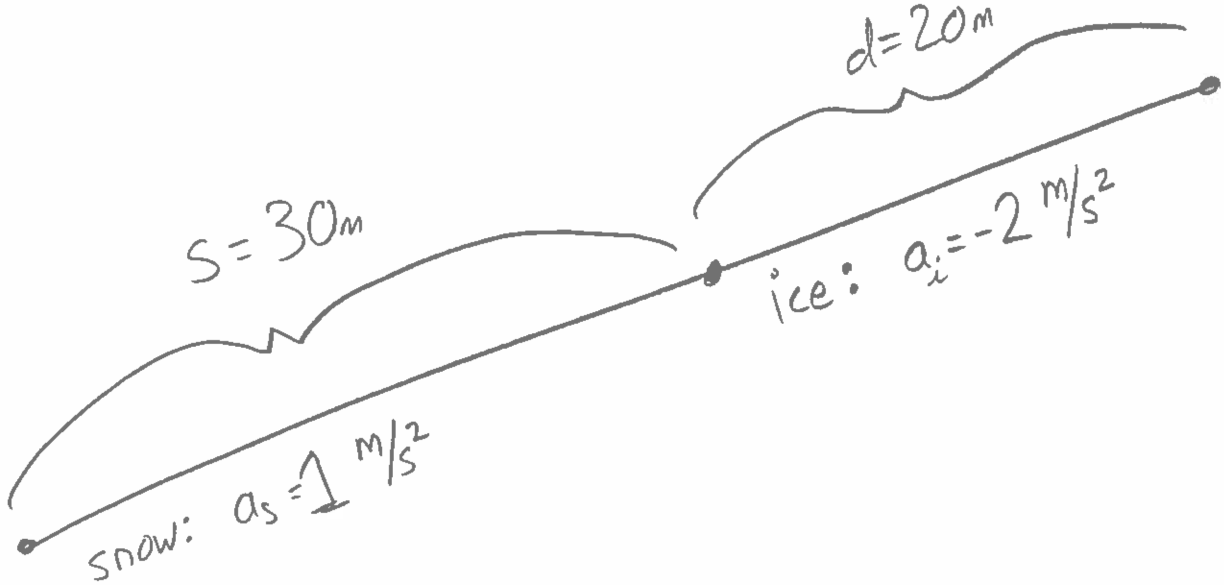

$\sin\theta = \dfrac{100 \text{ mph}}{400 \text{ mph}}$

$\theta = \arcsin 1/4 = 22.5°$ west of south

e) Use Pythagorean theorem: $A^2 + C^2 = B^2 \rightarrow A^2 = 400^2 - 100^2$
$= 387$ mph.

$\text{time} = \dfrac{\text{distance}}{\text{speed}} = \dfrac{300 \text{ miles}}{387 \text{ mi/hr}} = 0.78$ hr.

#2




a) "What is $v$ at the time that $x=s$?"

→ On the snow, $x=\frac{1}{2}a_s t^2$

$V=a_s t$

- Find time that $x=s$ : $t=\sqrt{\frac{2s}{a_s}}$
- Find $v$ at that time : $V=a_s\sqrt{2s/a_s}=\sqrt{2sa_s}$.

or use "third kinematics equation":

$$V_f^2-\cancel{V_0^2}^{\,0}=2a_s(x_f-\cancel{x_0}^{\,0}) \rightarrow V_f=\sqrt{2a_s s}=7.7\ m/s.$$

b) "At what time is $x=d$?"

(using a second set of constant-accel kinematics)

$$X=\frac{1}{2}a_i t^2+\sqrt{2a_s s}\,t$$

$$V=a_i t+\sqrt{2a_s s}$$ ← don't actually need this one

#2 con't

- Set $x = d$ and solve for $t$:

$$d = \frac{1}{2} a_i t^2 + \sqrt{2 a_s s}\, t$$

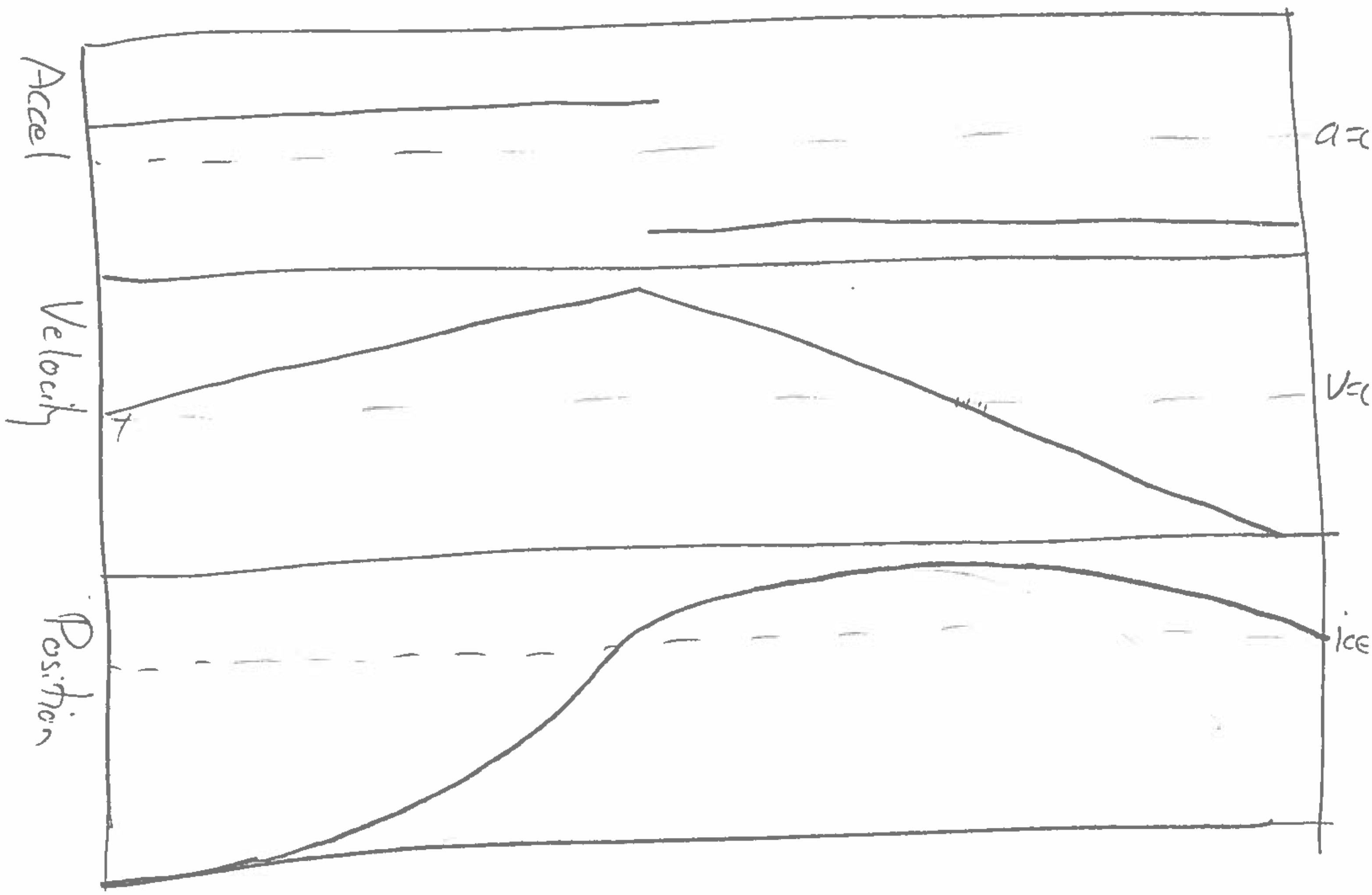
$$0 = \underbrace{\tfrac{1}{2}(-2\,m/s^2)}_{-1\,m/s^2} t^2 + (7.74\,m/s)t - 20\,m$$

Quadratic formula:

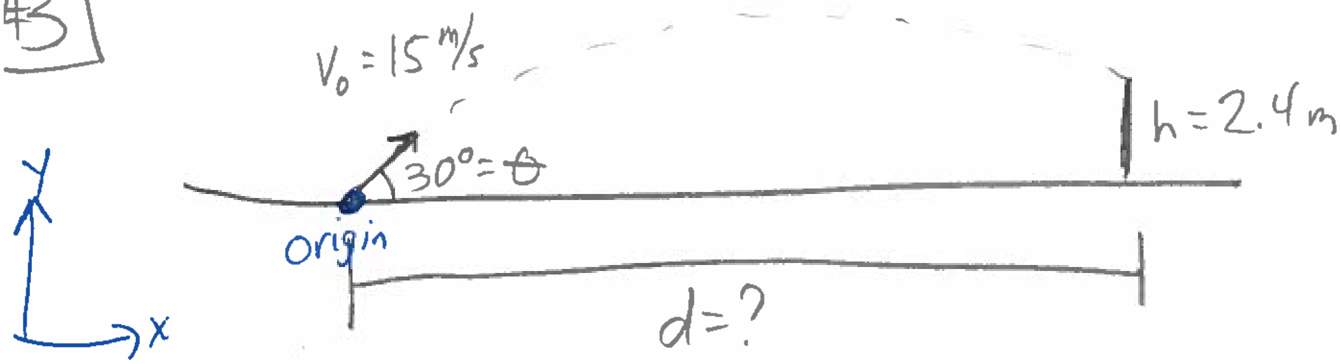
$$t = \frac{-7.74 \pm \sqrt{59.9 - 80}}{-2}$$

answer is imaginary.

Driver is sad.



3




i) $x(t) = (V_0 \cos\theta)t$

$y(t) = (V_0 \sin\theta)t - \frac{1}{2}gt^2$

b) "What time is $y = h$?"

$$h = (V_0 \sin\theta)t - \frac{1}{2}gt^2 \longrightarrow \frac{1}{2}gt^2 - (V_0 \sin\theta)t + h = 0$$

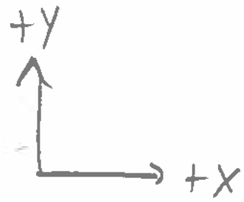
$$t = \frac{V_0 \sin\theta \pm \sqrt{V_0^2 \sin^2\theta - 2gh}}{g}$$

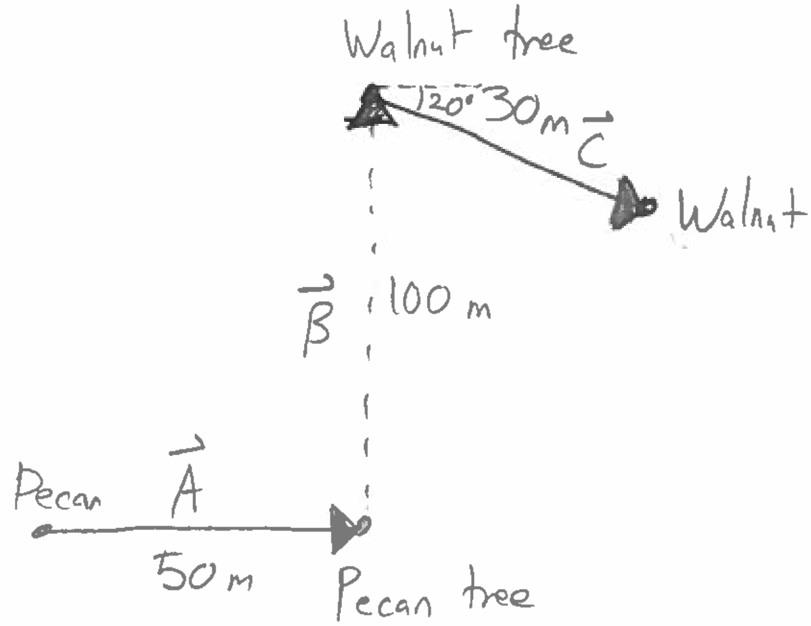
b and c): The ball hits the crossbar on the way back down according to the picture. That corresponds to the + sign. The − sign gives you the earlier time the ball was at that height.

d) Find $x(t)$ at that time:

$$d = (V_0 \cos\theta)t = V_0 \cos\theta \, \frac{V_0 \sin\theta + \sqrt{V_0^2 \sin^2\theta - 2gh}}{g}$$

# 4




$\vec{A} = (50, 0)$

$\vec{B} = (0, 100)$

$\vec{C} = (30 \cos 20°, -30 \sin 20°)$

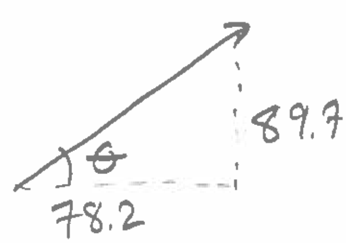
Pecan to walnut $= \vec{A} + \vec{B} + \vec{C} = (50 + 30 \cos 20°, 100 - 30 \sin 20°)$

$= (78.2, 89.7)$

a)
Use Pythagorean theorem to find magnitude of $(\vec{A} + \vec{B} + \vec{C})$

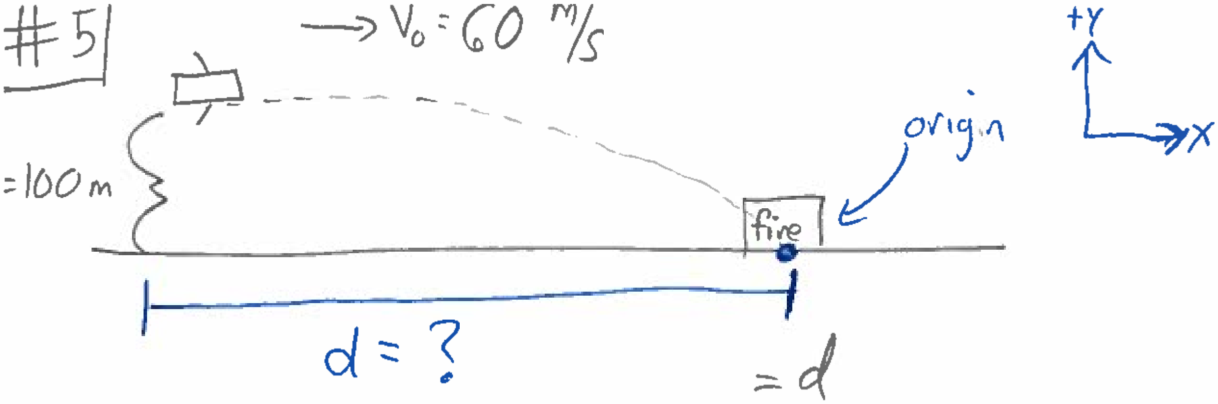
$= \sqrt{78.2^2 + 89.7^2} = 119$ m.

b) Find direction of that vector:




$\theta = 48.9°$ north of east

# #5




a) "What value of $x_0$ makes it so that $x = 0$ at the same time that $y = 0$?"

$$x(t) = v_0 t - d \qquad V_x(t) = V_0$$
$$y(t) = h - \tfrac{1}{2} g t^2 \qquad V_y(t) = -gt$$

$$0 = v_0 t - d$$
$$0 = h - \tfrac{1}{2} g t^2 \implies t = \sqrt{\frac{2h}{g}}$$

Substitute:

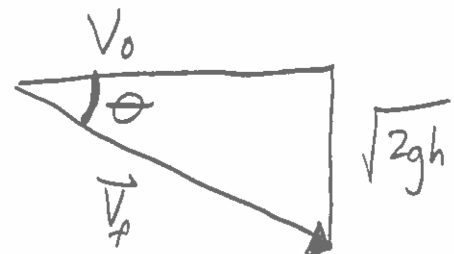
$$d = V_0 \sqrt{\frac{2h}{g}} = 271 \text{ m}$$

---

b) "What is the direction of $\vec{v}$ at the time $y = 0$?"

$$V_x = V_0 \qquad V_y = -g\sqrt{2h/g} = -\sqrt{2gh}$$

$$\tan\theta = \frac{\sqrt{2gh}}{V_0} \;;\; \theta = \tan^{-1} \frac{\sqrt{2gh}}{V_0}$$

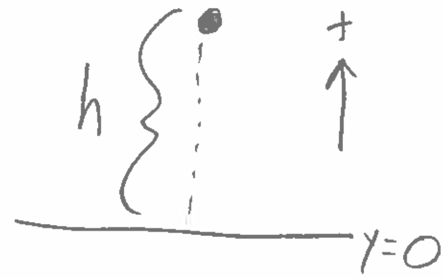



$\theta = 36.4$ degrees below horizontal

5 cont.

Directly above. The sand accelerates downward, but this doesn't affect its horizontal motion; in the x-direction it continues moving at the same rate as the plane.

$\boxed{\#6}$ a) This is just freefall in one dimension from rest.




$$y(t) = -\tfrac{1}{2}gt^2 + h$$

"When is $y=0$?" $\Rightarrow 0 = -\tfrac{1}{2}gt^2 + h$

$$\Rightarrow t = \sqrt{2h/g}$$

---

b) "What is $v$ at the time when $\underline{y=0}$?"

$\bullet\; v(t) = \cancel{v_0}^{\,0} - gt \longrightarrow v = -g\sqrt{2h/g} = -\sqrt{2gh}$

---

c) After bounce, need a new "set" of kinematics relations, with $V_0 = -\tfrac{1}{2}V_f$ from the previous phase: $\dfrac{\sqrt{2gh}}{2} = \sqrt{\dfrac{2gh}{4}} = \sqrt{\dfrac{gh}{2}}$.

So:

$$y(t) = -\tfrac{1}{2}gt^2 + \sqrt{\tfrac{gh}{2}}\,t \quad \text{and} \quad v(t) = -gt + \sqrt{\tfrac{gh}{2}}.$$

Highest point happens at the time $v=0$:

$$0 = -gt + \sqrt{\tfrac{gh}{2}} \longrightarrow t = \sqrt{\tfrac{h}{2g}}$$

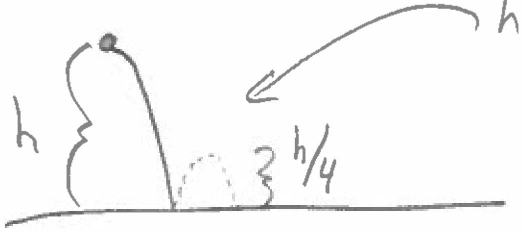
Height at that time:

$$y(t) = -\tfrac{1}{2}g\left[\tfrac{h}{2g}\right] + \sqrt{\tfrac{gh}{2}}\sqrt{\tfrac{h}{2g}} = -\tfrac{1}{4}h + \tfrac{1}{2}h = \tfrac{1}{4}h$$

#6, cont.

d) We have time from first drop to hitting ground the first time — now we need how long it takes to land again.

how long does this part take?

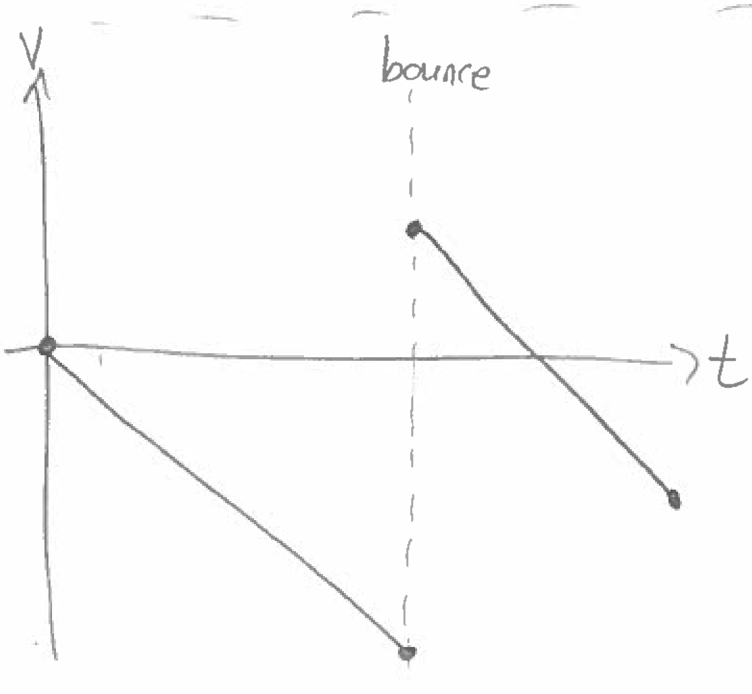


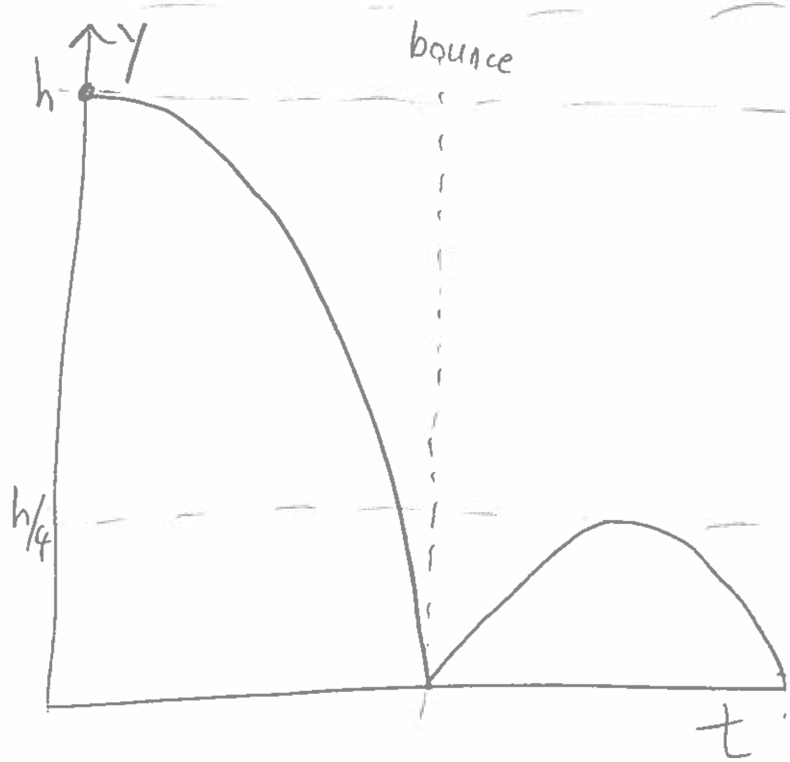

"What is $t$ when $y=0$?" (again)

$$y(t) = \underbrace{-\frac{1}{2}gt^2 + \sqrt{\frac{gh}{2}}\,t = 0}_{\text{factor this}} = \cancel{t}\left(-\frac{1}{2}gt + \sqrt{\frac{gh}{2}}\right)$$

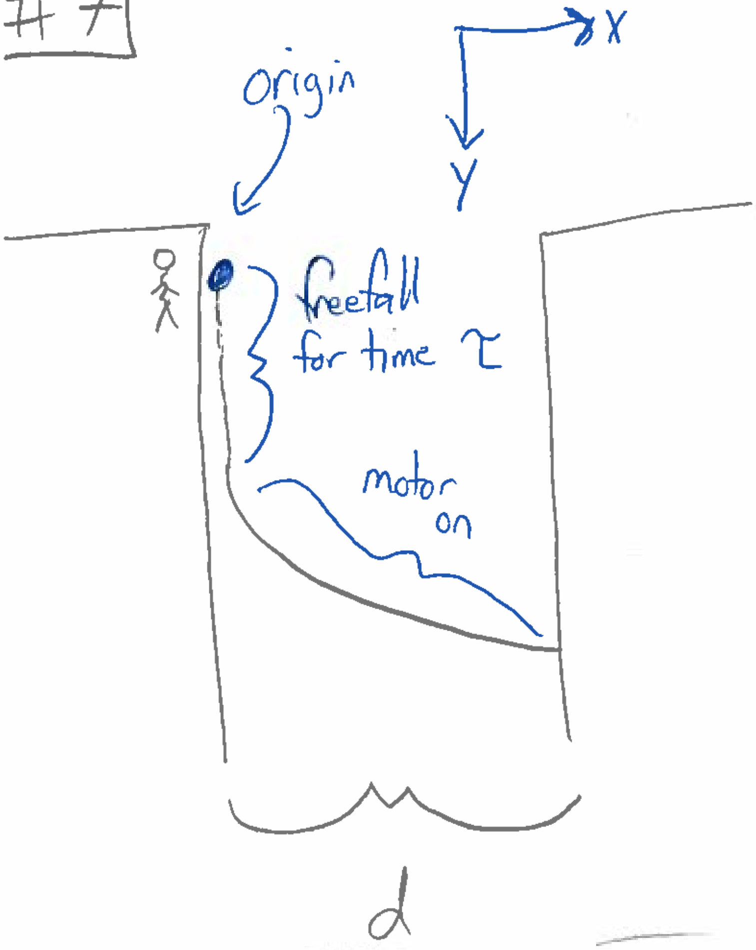
$$\Rightarrow t = \left(\frac{2}{g}\right)\left(\sqrt{\frac{gh}{2}}\right) = \sqrt{\left(\frac{4}{g^2}\right)\left(\frac{gh}{2}\right)} = \sqrt{\frac{2h}{g}}$$

- Total is the sum of this time plus the time to hit the first time: $t_{total} = \sqrt{\frac{2h}{g}} + \sqrt{\frac{2h}{g}} = 2\sqrt{\frac{2h}{g}}$.



# #7




a) Before the rocket fires, it is in freefall:

$y(t) = \frac{1}{2}gt^2$

$\rightarrow \frac{1}{2}g\tau^2$ below the window

$v_y(t) = gt$

$\rightarrow$ velocity of $g\tau$ in the y-direction and $0$ in $x$

b) After motor is fired:

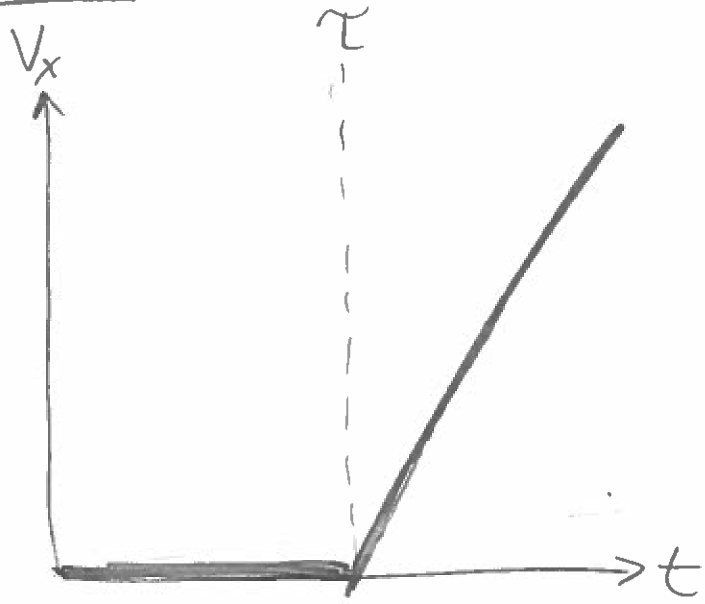
$x(t) = \frac{1}{2}(2g)t^2$

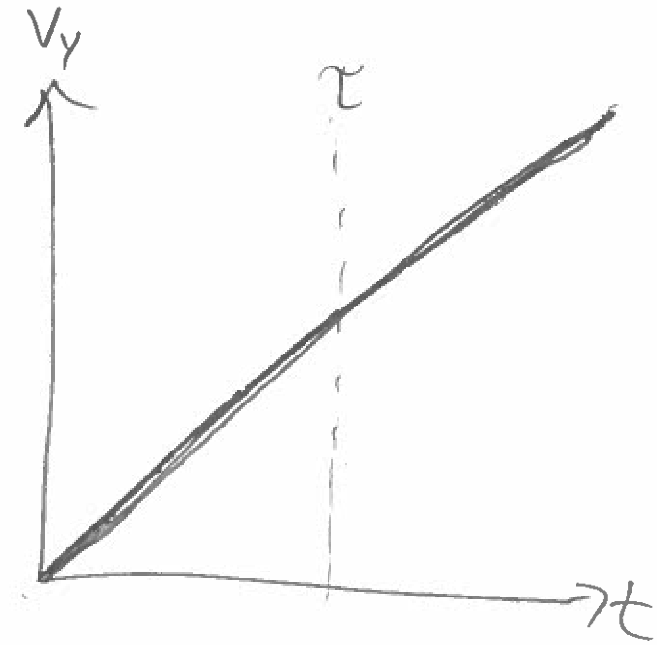
Rocket hits building when $x(t) = d \rightarrow d = gt^2,$

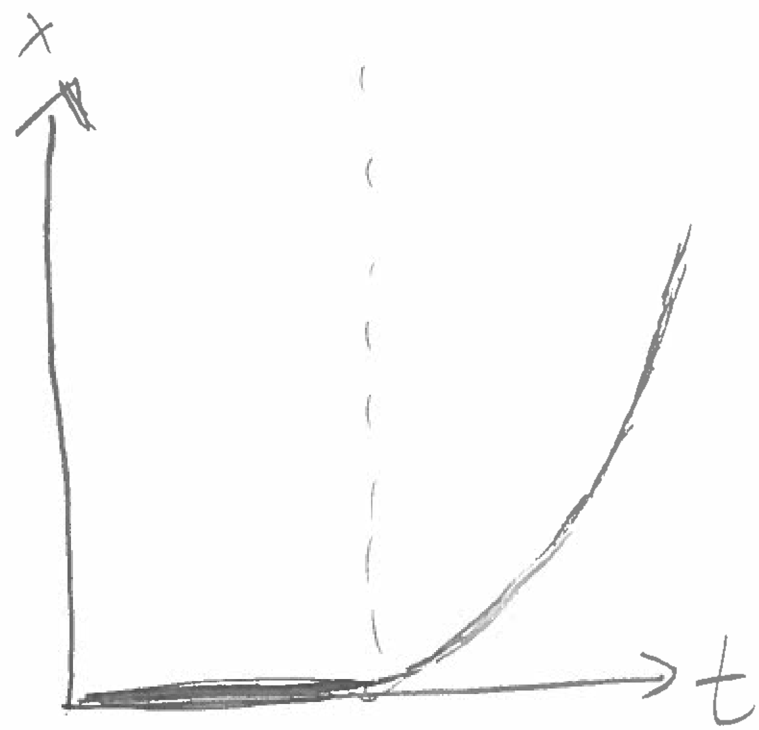
so it hits the building a time $\tau_2 = \sqrt{d/g}$ after motor fires.

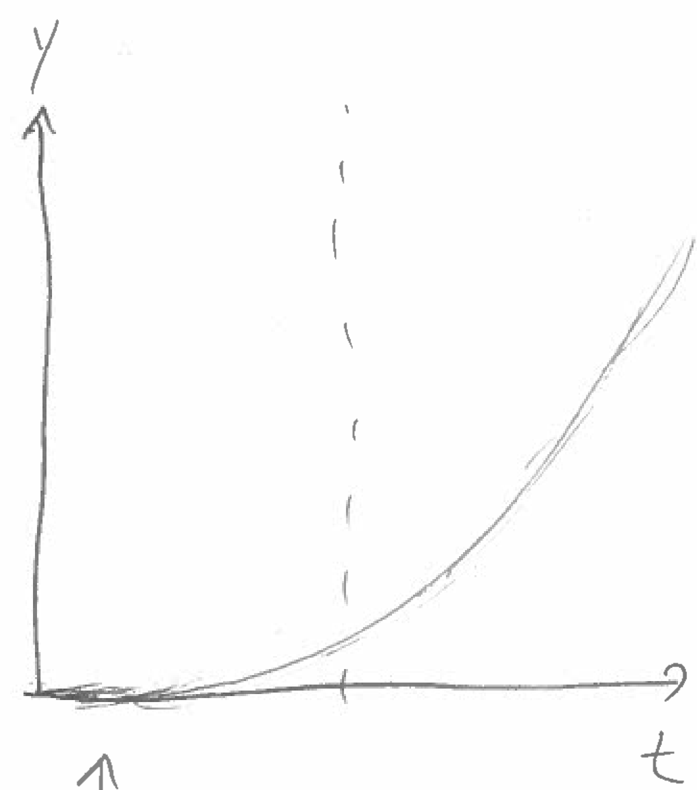
So the total time in the air is $\tau + \tau_2 = \tau + \sqrt{d/g}$

7 cont.



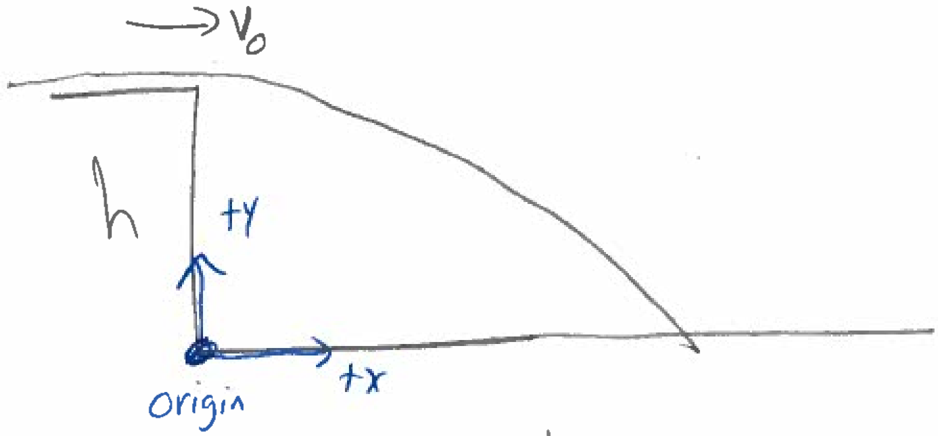




note: remember down is positive

# #8




a) "What is the time when $y=0$?"

$$y = h - \tfrac{1}{2}gt^2 \longrightarrow 0 = h - \tfrac{1}{2}gt^2 \Rightarrow t = \sqrt{\frac{2h}{g}}.$$

b) "What is x at that time?"

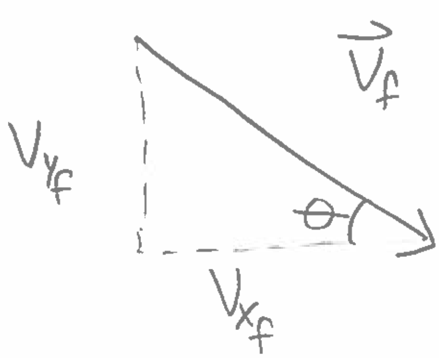
$$x = v_0 t \longrightarrow x = v_0\sqrt{2h/g}.$$

c) Find magnitude of $\vec{v}$ at that time.

- $v_x = v_0$
- $v_y = -gt \longrightarrow$ at floor, $v_y = -\sqrt{2gh}$

$$\text{Magnitude} = \sqrt{v_x^2 + v_y^2} = \sqrt{v_0^2 + 2gh}$$

d) Find direction of $\vec{v}$:




$$\theta = \tan^{-1}\frac{V_{y_f}}{V_{x_f}} = \tan^{-1}\frac{\sqrt{2gh}}{V_0}$$

below the horizontal

## #8 cont.

e) Now I need to decompose the initial velocity vector into x- and y-components, and

$V_x = V_0 \cos\theta$, $V_y = V_0 \sin\theta$.

Nothing else changes in the approach.