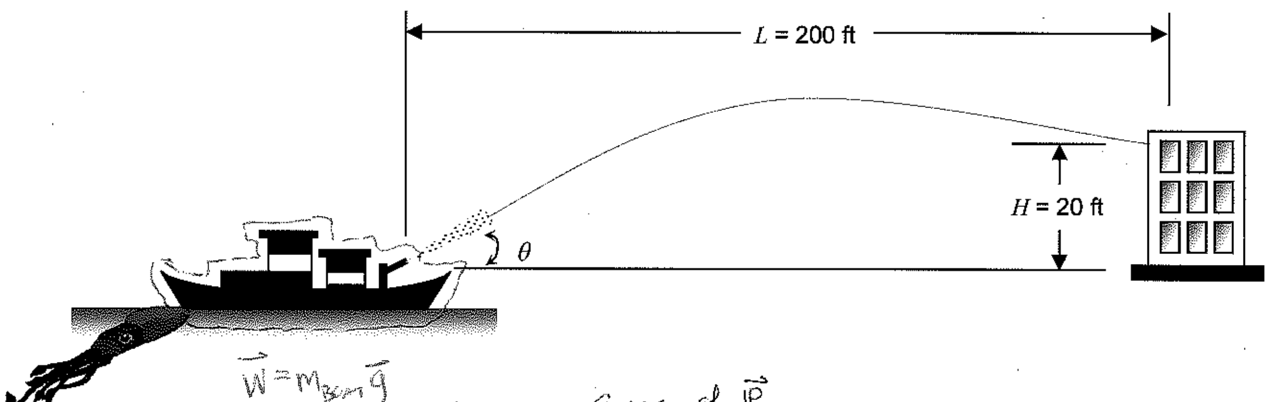
Example

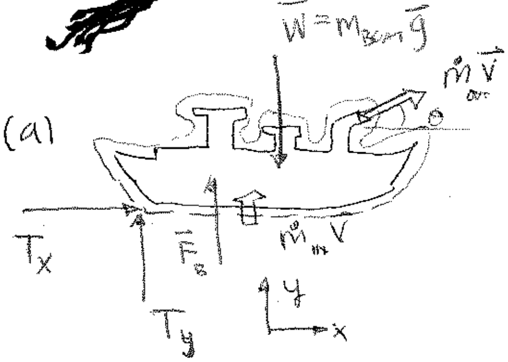
A hose discharges water at a rate of $\dot{\forall} = 2000$ gal/min with a speed of $V_0 = 100$ ft/s from the stern of a fireboat. The stream is used to extinguish a building fire on shore. Water is drawn into the boat vertically from the river with negligible velocity. In order to keep the boat stationary in the water, Iggy the Giant Firefighter Squid pushes on the boat as shown in the figure,

(a) Determine the horizontal component of the force Iggy must exert in order to keep the fireboat stationary position. (1 ft³ = 7.48 gal)

(b) At what angle should the hose be set? (Hint: Pick a closed system consisting of a water droplet and follow it as it travels to the building.)



(a)



Cons. of $\vec{P}$

$$\frac{d}{dt}(\vec{P}_{sys}) = \Sigma \vec{F} + \Sigma \dot{m}_{in}\vec{V}_{in} - \Sigma \dot{m}\vec{V}_{out}$$

x-direction.

$$\frac{d}{dt}(m_{boat} \underbrace{V_{boat,x}}_{\to 0}) = \Sigma F_x + \dot{m}_{in}(V_{x,in}) - \dot{m}_{out}(V_{x,out})$$

$$0 = T_x - \dot{m}_{out} V_0 \cos\theta$$

$$T_x = \dot{m}_{out} V_0 \cos\theta$$

$$T = \rho \dot{\forall}_{out} V_0 \cos\theta = ?$$

What is θ?

Let us look @ y-direction

y-direction:

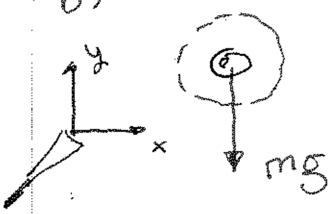
$$\frac{d}{dt}(m_{Boat} \underbrace{V_{boat,y}}_{\to 0}) = \Sigma F_y + \dot{m}_{in} \underbrace{V_{y,in}}_{\to 0} - \dot{m}_{out} V_{y,out}$$

$$0 = T_y - W + F_B - \dot{m} V_0 \sin\theta$$

$$T_y = \dot{m} V_0 \sin\theta + W - F_B$$

No help...

b)



ORIGIN @
HOSE EXIT

$$\frac{d}{dt}\left(\vec{P}_{sys}\right) = \Sigma \vec{F}_{EXTERNAL} + \cancel{\Sigma}_{0}$$

$\cancel{\ }_{0}$ CLOSED

$$\frac{d}{dt}\left(m\vec{V}\right) = \Sigma\vec{F}_{EXT}$$

X-DIR →

$$\frac{d}{dt}\left(m V_x\right) = 0 \qquad \frac{d}{dt}\left(V_x\right) = 0 \qquad V_x = c_1 = V_{x,0} \text{ (I.C.)} \qquad \frac{d}{dt}(x) = V_{x,0}$$

$$\boxed{x = V_{x,0}\, t} + \cancel{c_2}_{0} \quad \text{(I.C.)}$$

(2)

y-DIR →

$$\frac{d}{dt}\left(\cancel{m} V_y\right) = -g\cancel{m} \qquad \frac{d}{dt}\left(V_y\right) = -g \qquad V_y = -gt + c_1 = -gt + V_{y,0} \text{ (I.C.)} \qquad \frac{d}{dt}(y) = -gt + V_{y,0}$$

$$\boxed{y = -\frac{gt^2}{2} + V_{y,0}\, t} + \cancel{c_2}_{0} \quad \text{(I.C.)}$$

- WANT X TO BE 200'
- " y " " 20'

$$200 = \overset{?}{V}_{x,0}\, \overset{?}{t}$$

$$20 = -\frac{gt^2}{2} + \overset{?}{V}_{y,0}\, \overset{?}{t}$$

$V_{x,0}$ & $V_{y,0}$ BOTH UNKNOWNS?
NO!

$V_{x,0} = V\cos\theta$ — 100 ft/s

$V_{y,0} = V\sin\theta$

THUS

$$\left.\begin{aligned} 200 &= V\cos\theta\, t \\ 20 &= -\frac{gt^2}{2} + V\sin\theta\, t \end{aligned}\right\}$$

$\theta = 69°$ $\quad t = 5.58\,s$

OR

$$\boxed{\theta = 26.7° \qquad t = 2.24\,s}$$

BACK TO a)

$$\mathbb{T}_x = \rho \dot{\forall}_w V_w = 62.4 \frac{\text{lbm}}{\text{ft}^3} \times 2000 \frac{\cancel{\text{gal}}}{\cancel{\text{min}}} \times 160 \frac{\text{ft}}{\text{s}} \cos(26.7°) \left\langle \frac{\text{ft}^3}{7.48\,\cancel{\text{gal}}} \right\rangle \left\langle \frac{1\,\cancel{\text{min}}}{60\,\text{sec}} \right\rangle$$

$$= 24{,}842 \frac{\cancel{\text{lbm-ft}}}{\cancel{\text{s}^2}} \left\langle \frac{\cancel{\text{s}^2}\cdot \text{lbF}}{32.2\ \cancel{\text{lbm}\cdot\text{ft}}} \right\rangle$$

$$= \boxed{772\ \text{lbF}}$$