PHYS-2010

GENERAL PHYSICS I

DR. LUTTERMOSER'S CLASS

PROBLEM SET I

1. $$s = k a^m t^n$$

$[t] = T$ (time), $[a] = LT^{-2}$ (length per time squared)

$[k] = 1$ (unitless), $[s] = L$ (length = displacement)

$$[s] = [k][a]^m[t]^n$$

$$L = 1 \cdot (LT^{-2})^m (T)^n$$

$$L = L^m T^{-2m} T^n = L^m T^{n-2m}$$

As such, $m = 1$ for LHS = RHS in length, then

$$1 = T^{n-2m} = T^{n-2\cdot 1} = T^{n-2}$$

Since T does not appear on the LHS, $n = 2$, then

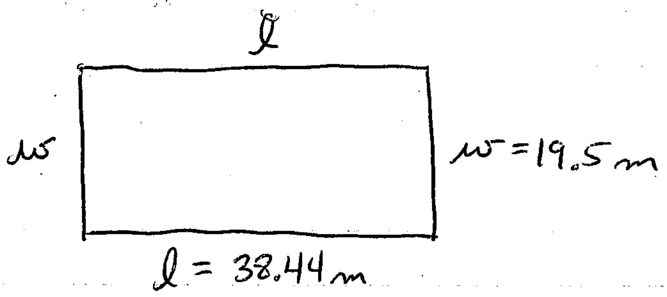
$$1 = T^{2-2} = T^0 = 1 \checkmark$$

The value for k can then be found with a little algebra:

$$s = k a t^2$$

$$\boxed{k = \frac{s}{at^2}}$$

2.



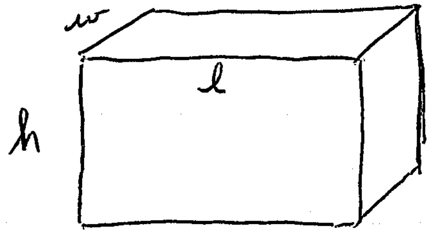
Total distance is $s = w + l + w + l = 2w + 2l$

$$s = 2(19.5\,m) + 2(38.44\,m) = 39.\underline{0}\,m + 76.88\,m$$

$$= 115.\underline{8}8\,m = \boxed{115.9\,m}$$

3.

$l = 50.0\,ft$
$w = 26\,ft$
$h = 8.0\,ft$



$$V = l w h$$
$$= (50.0\,ft)(26\,ft)(8.0\,ft)$$
$$= \underline{10}400\,ft^3 = 1\underline{0}\,000\,ft^3$$

$$1\,m = 39.37\,in = 3.281\,ft$$

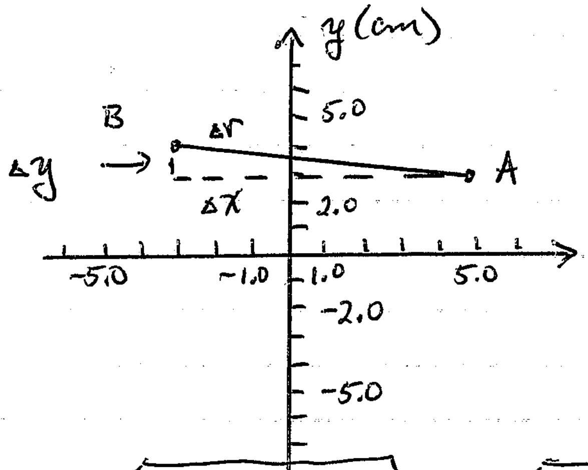
$$V = 1\underline{0}\,000\,ft^3 \times \left(\frac{1.000\,m}{3.281\,ft}\right)^3 = 2\underline{8}3.127\,m^3$$

$$= \boxed{280\,m^3}$$

$1\,m = 100\,cm$

$$V = 280\,m^3 \times \left(\frac{100\,cm}{1\,m}\right)^3 = \boxed{2.8 \times 10^8\,cm^3}$$

4.



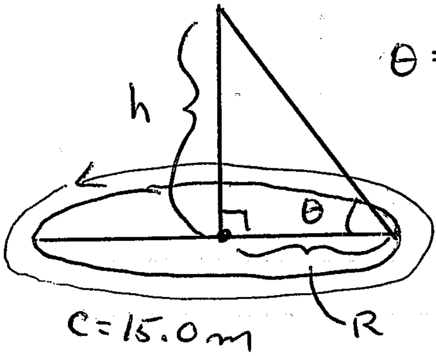
$(\Delta r)^2 = (\Delta x)^2 + (\Delta y)^2$

$\Delta x = x_A - x_B$
$= 5.0\text{ cm} - (-3.0\text{ cm})$
$= 8.0\text{ cm}$

$\Delta y = y_A - y_B$
$= 3.0\text{ cm} - 4.0\text{ cm}$
$= -1.0\text{ cm}$

$$\Delta r = \sqrt{(\Delta x)^2 + (\Delta y)^2} = \sqrt{(8.0\text{ cm})^2 + (-1.0\text{ cm})^2}$$
$$= \sqrt{64.\text{ cm}^2 + 1.0\text{ cm}^2} = \sqrt{65\text{ cm}^2} = \boxed{8.1\text{ cm}}$$

5.



$\theta = 55.0°$

C = circumference
$= \pi D$, D = diameter
$= 2\pi R$, R = radius

$$R = \frac{C}{2\pi} = \frac{15.0\text{ m}}{2\pi} = 2.39\text{ m}$$

h = height

Note that $\tan\theta = \frac{h}{R}$

or $h = R\tan\theta = (2.39\text{ m})\tan 55.0°$

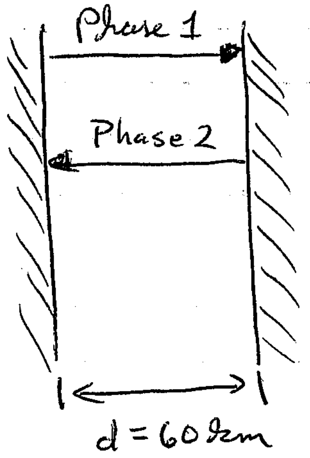
$= \boxed{3.41\text{ m}}$

6.

Phase 1: across lake (+x dir), $v_{A1} = 60 \frac{km}{h}$, $v_{B1} = 30 \frac{km}{h}$

Phase 2: return (−x dir), $v_{A2} = -60 \frac{km}{h}$, $v_{B2} = -90 \frac{km}{h}$

a)



$$t = \frac{d}{|v|}$$

$$t_{A1} = \frac{60\,km}{60\,km/h} = 1.0\,h$$

$$t_{B1} = \frac{60\,km}{30\,km/h} = 2.0\,h$$

$$t_{A2} = \frac{60\,km}{60\,km/h} = 1.0\,h$$

$$t_{B2} = \frac{60\,km}{90\,km/h} = \frac{2}{3}\,h = 0.67\,h$$

$t_A = t_{A1} + t_{A2} = 2.0\,h$, $t_B = t_{B1} + t_{B2} = 2.7\,h$

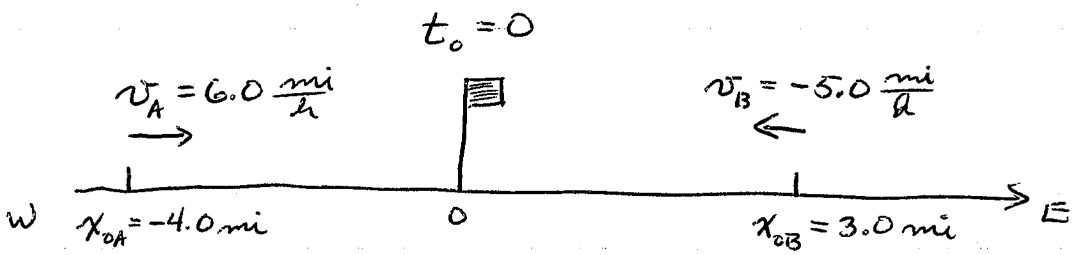
$\boxed{t_A < t_B\text{, boat A wins!}}$ by $\Delta t = t_B - t_A = \boxed{0.7\,h}$ and distance of $\boxed{60\,km}$

b) $$\overline{v_A} = \frac{v_{A1} + v_{A2}}{2} = \frac{60\,\frac{km}{h} - 60\,\frac{km}{h}}{2} = \boxed{0}$$

or by calculating displacement over time:

$$\overline{v_A} = \frac{x_{A1} + x_{A2}}{t_{A1} + t_{A2}} = \frac{60\,km - 60\,km}{2.0\,hr} = 0 \checkmark$$

7.



$$x_A = x_{0A} + v_A t, \quad x_B = x_{0B} + v_B t$$

Find t when $x_A = x_B$: $\quad x_{0A} + v_A t = x_{0B} + v_B t$

$$v_A t - v_B t = x_{0B} - x_{0A}$$

$$(v_A - v_B)t = x_{0B} - x_{0A}$$

$$t = \frac{x_{0B} - x_{0A}}{v_A - v_B} = \frac{3.0\ mi - (-4.0\ mi)}{6.0 \frac{mi}{h} - (-5.0 \frac{mi}{h})} = \frac{7.0\ mi}{11.0\ mi/h}$$

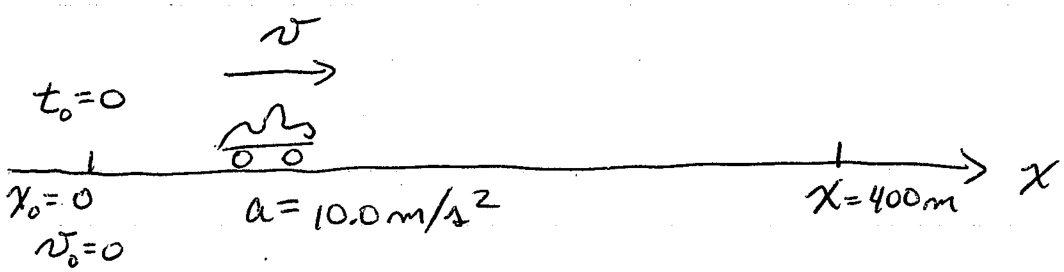
$$= 0.63636\ hr$$ (Keep extra digits to avoid round-off error below)

Final position: $x_A = x_{0A} + v_A t = -4.0\ mi + (6.0 \frac{mi}{h}) \times (0.63636\ hr)$

$$= -0.18\ mi$$

$$\boxed{x_f = 0.18\ mi\ \text{W of flagpole.}}$$

8.



a) Time to get to $x=400\,m$:

We can use: $x = x_0 + v_0 t + \frac{1}{2}at^2$

where $v_0 = 0$ (starts from rest) and $x_0 = 0$.

Now, solve for t: $x = 0 + 0 + \frac{1}{2}at^2$

$$t^2 = \frac{2x}{a}$$

$$t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2(400\,m)}{10.0\,m/s^2}}$$

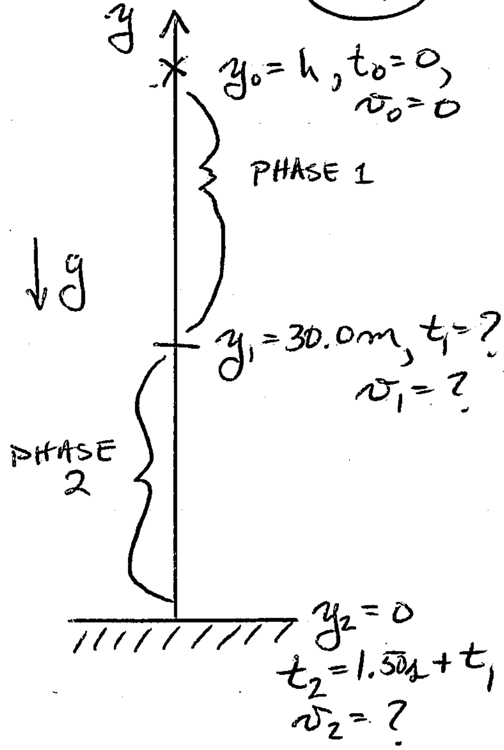
$$= \sqrt{80.0\,s^2} = \boxed{8.94\,s}$$

b) Need v at $x=400\,m$:

Use: $v = v_0 + at = 0 + at$

$$v = \left(10.0\,\frac{m}{s^2}\right)(8.94\,s) = \boxed{89.4\,m/s}$$

9.



During Phase 2, we have

$$y_2 = y_1 + v_1(t_2 - t_1) - \tfrac{1}{2}g(t_2 - t_1)^2$$

$$t_2 - t_1 = 1.50\,s, \quad y_2 = 0$$
$$y_1 = 30.0\,m$$

$$0 = y_1 + v_1(t_2 - t_1) - \tfrac{1}{2}g(t_2 - t_1)^2$$
$$v_1(t_2 - t_1) = -y_1 + \tfrac{1}{2}g(t_2 - t_1)^2$$

$$v_1 = -\frac{y_1}{(t_2 - t_1)} + \frac{g}{2}(t_2 - t_1)$$
$$= -\frac{30.0\,m}{1.50\,s} + \frac{9.80\,m/s^2}{2}(1.50\,s) = -20.0\,\frac{m}{s} + 7.35\,\frac{m}{s}$$
$$= -12.65\,\frac{m}{s} = -12.7\,\frac{m}{s}$$

During Phase 1, we have

$$v_1^2 = v_0^2 - 2g(y_1 - y_0), \quad v_0 = 0,\ y_0 = h$$
$$2g(y_1 - h) = -v_1^2, \quad y_1 - h = \frac{-v_1^2}{2g}$$
$$h = y_1 + \frac{v_1^2}{2g} = 30.0\,m + \frac{(-12.7\,m/s)^2}{2(9.80\,m/s^2)}$$
$$= 30.0\,m + 8.16\,m = 38.16\,m$$
$$= \boxed{38.2\,m}$$

10.

Label Kathy variables with a 'K' and Stan variables with an 'S', then our given parameters are

$a_K = 4.90\,\frac{m}{s^2}$, $v_{oK} = 0\,\frac{m}{s}$, $t_{oK} = 0\,s$, $x_{oK} = 0\,m$

$a_S = 3.50\,\frac{m}{s^2}$, $v_{oS} = 0\,\frac{m}{s}$, $t_{oS} = -1.00\,s$, $x_{oS} = 0\,m$

a) Determine the time when $x_K = x_S$:

$$x_K = x_{oK} + v_{oK}(t - t_{oK}) + \tfrac{1}{2}a_K(t - t_{oK})^2$$
$$= 0 + 0 + \tfrac{1}{2}a_K(t-0)^2 = \tfrac{1}{2}a_K t^2$$
$$x_S = x_{oS} + v_{oS}(t - t_{oS}) + \tfrac{1}{2}a_S(t - t_{oS})^2$$
$$= 0 + 0 + \tfrac{1}{2}a_S(t - t_{oS})^2 = \tfrac{1}{2}a_S(t - t_{oS})^2$$

Now,

$$x_K = x_S$$
$$\tfrac{1}{2}a_K t^2 = \tfrac{1}{2}a_S(t - t_{oS})^2$$
$$a_K t^2 = a_S(t - t_{oS})^2$$

Take square-root of both sides:

$$\sqrt{a_K}\,t = \sqrt{a_S}\,(t - t_{oS})$$

Now solve for t:

$$\sqrt{a_K}\,t - \sqrt{a_S}\,t = -\sqrt{a_S}\,t_{0S}$$

$$(\sqrt{a_K} - \sqrt{a_S})\,t = -\sqrt{a_S}\,t_{0S}$$

$$t = -\frac{\sqrt{a_S}}{(\sqrt{a_K} - \sqrt{a_S})}\,t_{0S}$$

$$= -\frac{\sqrt{3.50\,m/s^2}}{(\sqrt{4.90\,m/s^2} - \sqrt{3.50\,\frac{m}{s^2}})}\,(-1.00\,s)$$

$$= \frac{1.87}{0.343}\,(1.00\,s) = \boxed{5.46\,s}$$

They meet 5.46 s after Kathy starts.

b) Distance traveled when $x_K = x_S$:

$$x_S = x_K = \frac{1}{2}a_K t^2 = \frac{1}{2}(4.90\,\tfrac{m}{s^2})(5.46\,s)^2$$

$$= \boxed{73.0\,m}$$

c) Find v_K and v_S when $x_K = x_S$:

$$v_K = v_{0K} + a_K(t - t_{0K})$$

$$= 0 + a_K(t - 0) = a_K t$$

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$$v_K = \left(4.90\ \frac{m}{s^2}\right)(5.46\,s) = \boxed{26.8\ m/s}$$

$$v_s = v_{0s} + a_s\,(t - t_{0s})$$

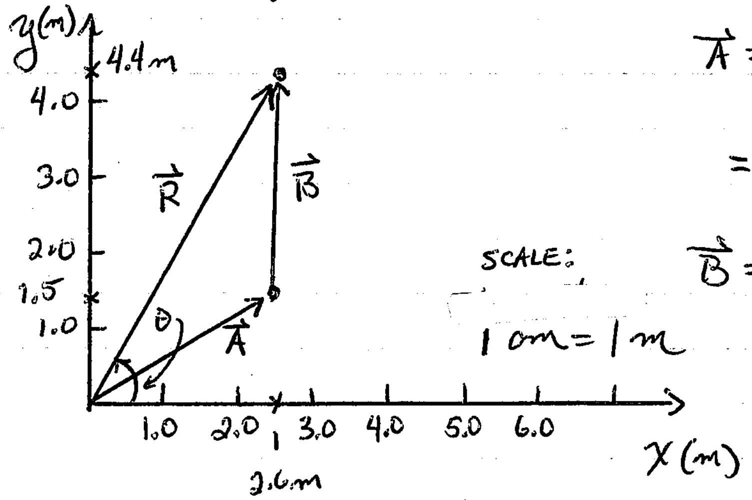
$$= 0 + \left(3.50\ \frac{m}{s^2}\right)\left(5.46\,s - (-1.00\,s)\right)$$

$$= \left(3.50\ \frac{m}{s^2}\right)(6.46\,s)$$

$$= \boxed{22.6\ m/s}$$

11.

a) $\vec{A}+\vec{B}$: Translate $\vec{B}$ so that it starts at the end of $\vec{A}$ for the graphical solution:



$$\vec{A} = [(3.00m)\cos 30°]\hat{x} + [(3.00m)\sin 30°]\hat{y} = (2.60m)\hat{x} + (1.50m)\hat{y}$$

$$\vec{B} = (3.00m)\hat{y}$$

Graphically: (measured) $\vec{R} = (2.6\,m)\hat{x} + (4.4\,m)\hat{y}$

$|\vec{R}| = R = 5.1\,m$, $\theta = 60°$ (measured)

Algebraically: $\vec{A}+\vec{B} = (2.60m + 0m)\hat{x} + (1.50m + 3.00m)\hat{y}$

$$\vec{R} = \vec{A}+\vec{B} = (2.60m)\hat{x} + (4.50\,m)\hat{y}$$

$$R = \sqrt{(2.60m)^2 + (4.50m)^2} = \sqrt{27.01\,m^2}$$

$$= \boxed{5.20\,m}$$

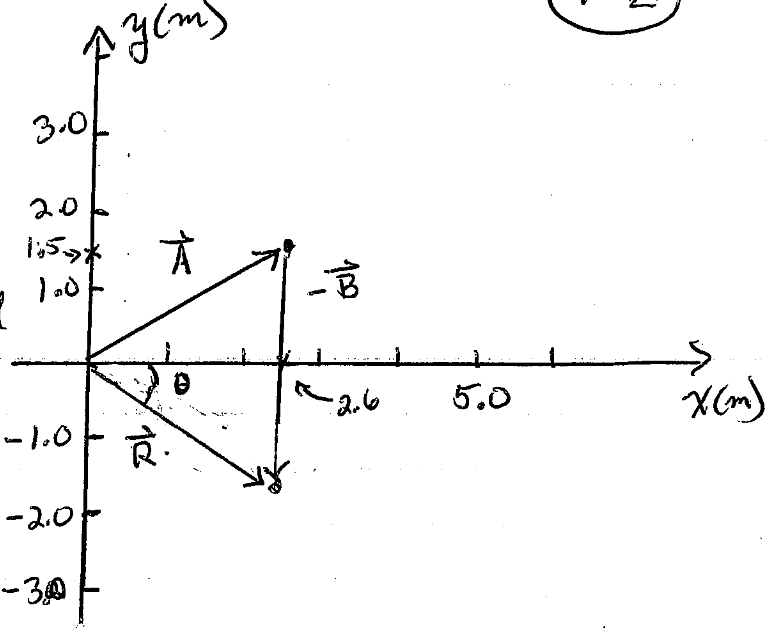
$\tan\theta = \frac{R_y}{R_x}$, $\theta = \tan^{-1}\left(\frac{4.50m}{2.60m}\right) = \boxed{60.0°}$

b) $\vec{A} - \vec{B}$

Graphically:

$R_x = 2.6\,m$
$R_y = -1.6\,m$
$R = 3.1\,m$
$\theta = -30^\circ$

} All measured



Algebraically:

$$\vec{R} = \vec{A} - \vec{B} = (2.60\,m - 0\,m)\,\hat{x} + (1.50\,m - 3.00\,m)\,\hat{y}$$

$$= (2.60\,m)\,\hat{x} - (1.50\,m)\,\hat{y}$$

$$R = |\vec{R}| = \sqrt{(2.60\,m)^2 + (-1.50\,m)^2}$$

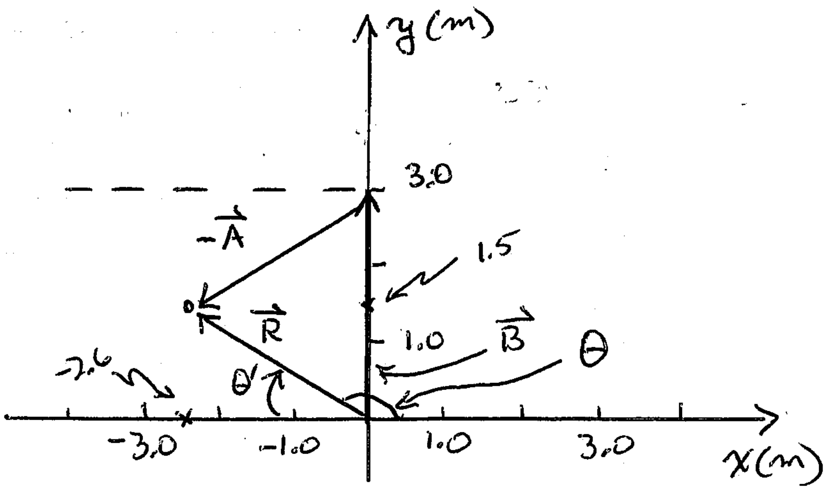
$$= \sqrt{9.01\,m^2} = \boxed{3.00\,m}$$

$$\theta = \tan^{-1}\left(\frac{-1.50\,m}{2.60\,m}\right) = \boxed{-30.0^\circ} = 330^\circ$$

c) $\vec{B} - \vec{A}$

Graphically:

$R_x = -2.6\,m$
$R_y = 1.5\,m$
$R = 3.0\,m$
$\theta = 150^\circ$



Algebraically:

$$\vec{R} = \vec{B} - \vec{A} = (0 - 2.60m)\hat{x} + (3.00m - 1.50m)\hat{y}$$
$$= -(2.60m)\hat{x} + (1.50m)\hat{y}$$

$$R = |\vec{R}| = \sqrt{(-2.60m)^2 + (1.50m)^2} = \sqrt{9.01 m^2}$$
$$= \boxed{3.00 m}$$

$$\theta' = \tan^{-1}\frac{R_y}{R_x} = \tan^{-1}\left(\frac{1.50m}{-2.60m}\right) = -30.0^\circ$$

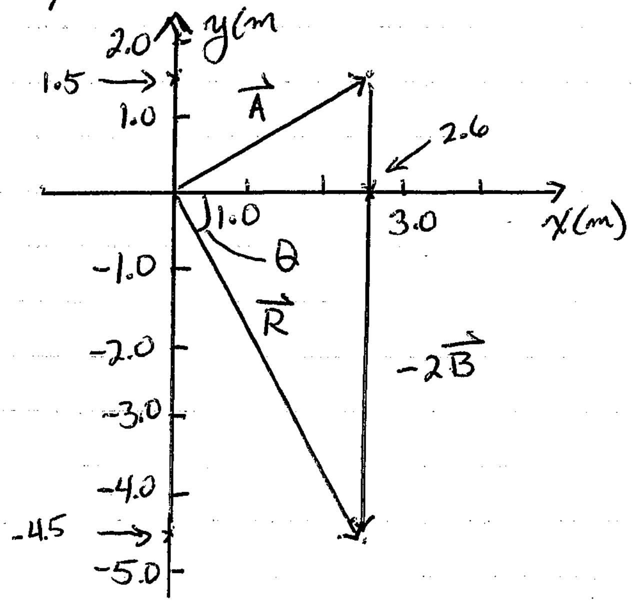
Note however that since we are in the 2nd quadrant, this θ (marked θ' here) is with respect to the $-x$ axis, the negative sign in θ' indicates the angle is clockwise wrt the $-x$ axis. As such,

$$\theta = 180^\circ + \theta' = 180^\circ - 30.0^\circ = \boxed{150.0^\circ}$$

d) $\vec{R} = \vec{A} - 2\vec{B}$

Graphically:

$\left.\begin{array}{l} R_x = 2.6m \\ R_y = -4.5m \\ R = 5.2m \\ \theta = -60^\circ \end{array}\right\}$ all measured



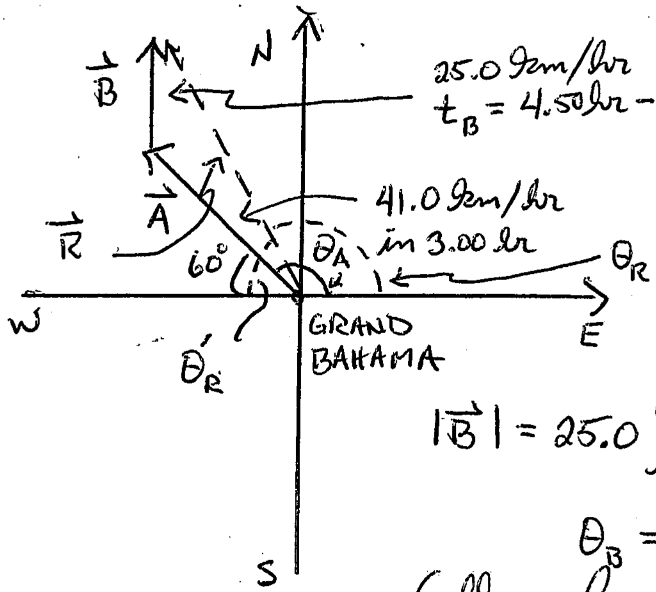
Algebraically:

$$\vec{R} = \vec{A} - 2\vec{B} = (2.60m - 0)\hat{x} + (1.50m - 2\times 3.00m)\hat{y}$$
$$= (2.60m)\hat{x} - (4.50m)\hat{y}$$

$$R = \sqrt{(2.60m)^2 + (-4.50m)^2}$$
$$= \boxed{5.20 m}$$

$$\theta = \tan^{-1}\left(\frac{-4.50m}{2.60m}\right) = \boxed{-60.0^\circ}$$

12.



$t_B = 4.50\,hr - 3.00\,hr = 1.50\,hr$

$\vec{R} = \vec{A} + \vec{B}$

$|\vec{A}| = 41.0\,\frac{km}{hr} \cdot 3.00\,hr$
$= 123.\,km$

$\theta_A = 180° - 60° = 120°$

$|\vec{B}| = 25.0\,\frac{km}{hr} \cdot 1.50\,hr = 37.5\,km$

$\theta_B = 90°$
(all angles wrt the eastern direction)

$\vec{R} = \vec{A} + \vec{B} = (A_x + B_x)\hat{x} + (A_y + B_y)\hat{y}$

$A_x = A\cos\theta_A = (123\,km)\cos 120° = -61.5\,km$
$A_y = A\sin\theta_A = (123\,km)\sin 120° = 106.5\,km$
$B_x = 0\,,\quad B_y = B = 37.5\,km$

$\vec{R} = (-61.5\,km + 0)\,\hat{x} + (106.5\,km + 37.5\,km)\,\hat{y}$
$= -(61.5\,km)\,\hat{x} + (144\,km)\,\hat{y}$

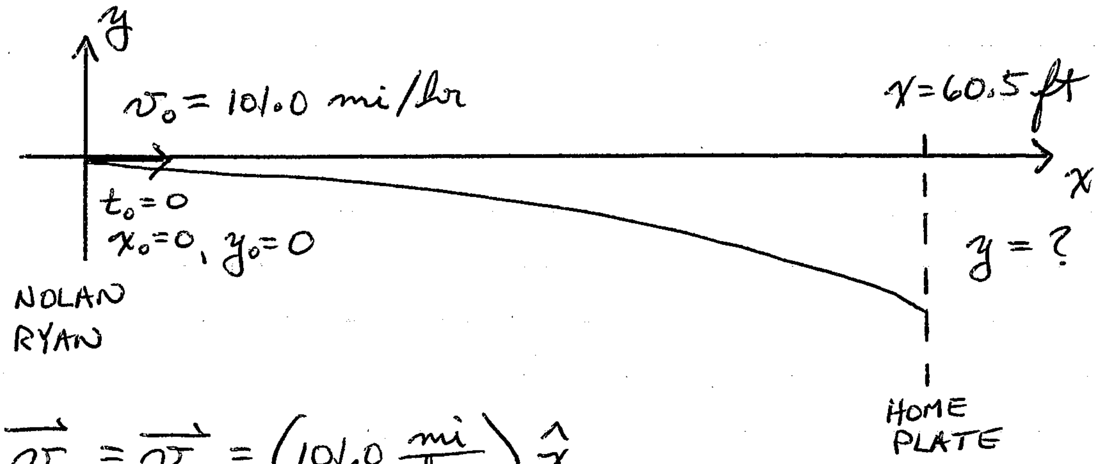
$R = \sqrt{(-61.5\,km)^2 + (144\,km)^2} = \boxed{157\,km}$ NW of Grand Bahama

$\theta_R' = \tan^{-1}\left(\frac{R_y}{R_x}\right) = \tan^{-1}\left(\frac{144\,km}{-61.5\,km}\right) = -66.9°$ (from the $-x$ or W direction)

$\theta_R = 180° + \theta_R' = 180° - 66.9 = \boxed{113°}$ from E direction

or $\boxed{67° \text{ N of W from Grand Bahama}}$

13.



$$\vec{v}_{0x} = \vec{v}_0 = \left(101.0\ \frac{mi}{hr}\right)\hat{x}$$
$$= \left(101.0\ \frac{mi}{hr} \times 5280\ \frac{ft}{mi} \times \frac{1\ hr}{3600\ s}\right)\hat{x}$$
$$= (148.1\ ft/s)\ \hat{x}$$

$$\vec{v}_{0y} = 0$$

Since there is no acceleration in the x-direction,

$$x = x_0 + v_{0x}t = v_{0x}t, \text{ or } t = \frac{x}{v_{0x}} = \frac{60.5\ ft}{148.1\ ft/s} = 0.409\ s$$

Now use

$$y = y_0 + v_{0y}t - \tfrac{1}{2}gt^2 = 0 + 0 - \tfrac{1}{2}\left(32.0\ \frac{ft}{s^2}\right)(0.409\ s)^2$$
$$= \boxed{-2.68\ ft}$$

The ball drops 2.68 ft from the y position that Billy Wagner pitches it.

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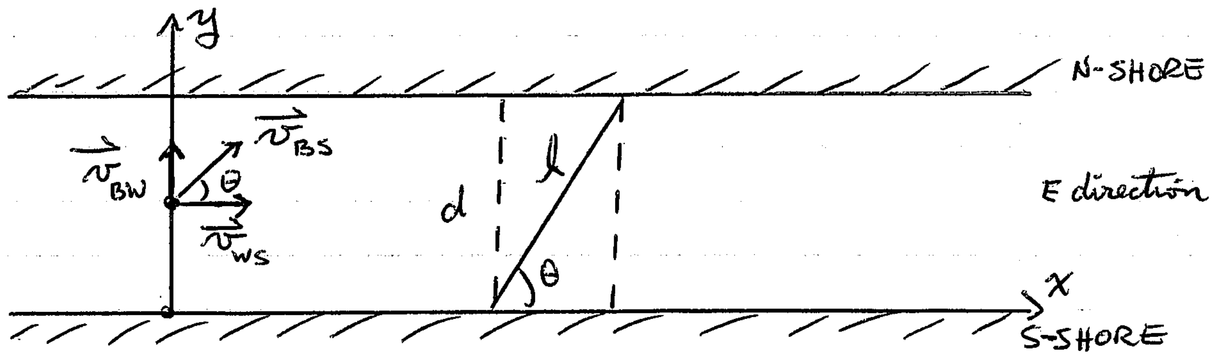
14.



Let $\vec{v}_{BW}$ be the velocity of the boat wrt the water,

$\vec{v}_{WS}$ " " " " " water " " shore,

$\vec{v}_{BS}$ " " " " " boat " " shore.

a) Find $\vec{v}_{BS}$:

$$\vec{v}_{BS} = \vec{v}_{WS} + \vec{v}_{BW}$$

$$\vec{v}_{WS} = (1.50 \text{ m/s})\,\hat{x} \qquad \text{(east direction)}$$

$$\vec{v}_{BW} = (10.0 \text{ m/s})\,\hat{y} \qquad \text{(north direction)}$$

$$\vec{v}_{BS} = (1.50 \text{ m/s})\,\hat{x} + (10.0 \text{ m/s})\,\hat{y}$$

$$v_{BS} = |\vec{v}_{BS}| = \sqrt{v_x^2 + v_y^2} = \sqrt{(1.50 \tfrac{m}{s})^2 + (10.0 \tfrac{m}{s})^2}$$

$$= \sqrt{(102.25 \text{ m}^2/\text{s}^2)} = \boxed{10.1 \tfrac{m}{s}}$$

θ = angle wrt south shore, so

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = \tan^{-1}\left(\frac{10.0\ m/s}{1.50\ m/s}\right)$$

$$= \tan^{-1}(6.667) = 81.5^\circ \text{ wrt the south shore}$$

or $90^\circ - 81.5^\circ = \boxed{8.5^\circ \text{ E of the N direction}}$

b) Let l be the actual path the boat travels across the river and d be the width of the river, then

$\sin\theta = \frac{d}{l}$ where this θ is the same θ as calculated with the velocity vectors

$$l = \frac{d}{\sin\theta} = \frac{300.\ m}{\sin 81.5^\circ} = 303\ m$$

The time to cross the river is found from

$v_{BS} = l/t$ or $t = l/v_{BS} = 303 m/10.1 m/s = 30.0 s$

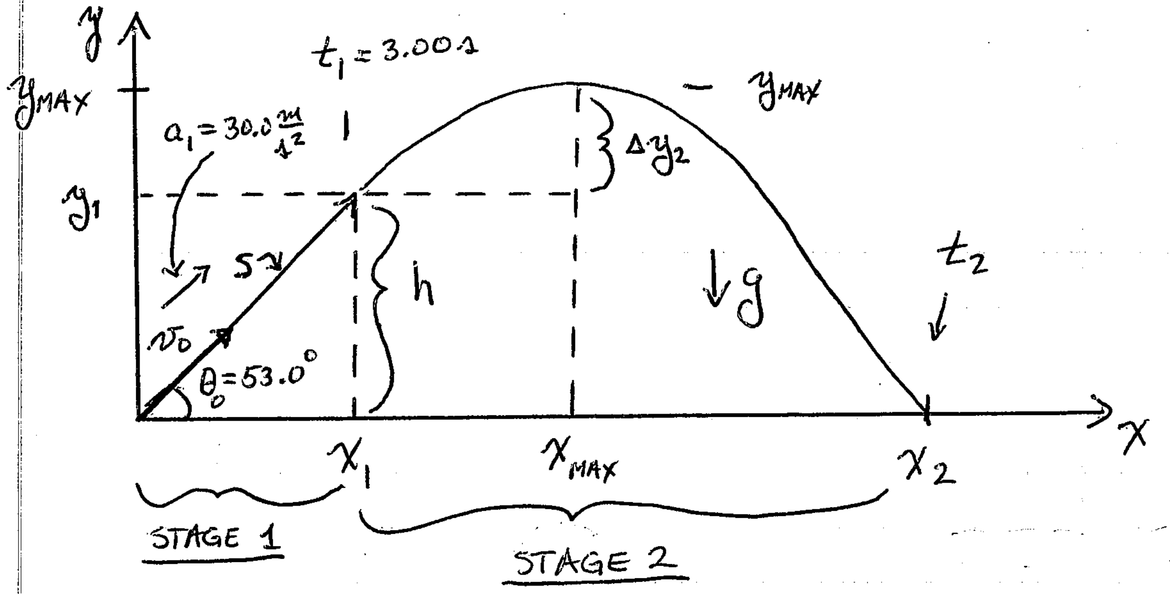
Let x be the eastward displacement that the boat experiences as it crosses the river, then

$$x = v_{BSx}\, t = v_{WS}\, t = (1.50\ \tfrac{m}{s})(30.0\ s)$$

x-component of v_{BS}

$$\boxed{x = 45.1\ m}$$

15.



a) Find y_{MAX}:

Break problem into 2 stages:

During stage 1, the total acceleration of the rocket is in the same direction as $\vec{v_0}$. During this stage, the rocket moves a distance s along the direction of $\vec{v_0}$:

$s = v_0 t_1 + \frac{1}{2} a_1 t_1^2$, where $v_0 = 100.\ m/s$,

$a_1 = 30.0 \frac{m}{s^2}$, and $t_1 = 3.00 s$:

$$s = \left(100. \frac{m}{s}\right)(3.00 s) + \frac{1}{2}\left(30.0 \frac{m}{s^2}\right)(3.00 s)^2$$

$$= 300.\ m + 135.\ m = 435.\ m$$

(1-19)

At this time, its location is x_1, where

$$x_1 = s\cos\theta_0 = (435.\,m)\cos 53.0^\circ = 262.\,m.$$

Its vertical height is

$$y_1 = h = s\sin\theta_0 = (435.\,m)\sin 53.0^\circ = 347.\,m$$

and its velocity at that point is

$$v_1 = v_0 + at = 100.\,\tfrac{m}{s} + \left(30.0\,\tfrac{m}{s^2}\right)(3.00\,s)$$

$$= 190.\,m/s$$

in the same direction as $\vec{v}_0$. This acts as a new initial velocity for stage 2. Breaking this velocity into its x & y components give

$$v_{1x} = v_1\cos\theta_0 = \left(190.\,\tfrac{m}{s}\right)\cos 53.0^\circ = 114.\,\tfrac{m}{s}$$

$$v_{1y} = v_1\sin\theta_0 = \left(190\,\tfrac{m}{s}\right)\sin 53.0^\circ = 152.\,\tfrac{m}{s}$$

At the maximum height, y_{MAX}, $v_y = 0$. Realizing that the acceleration during this stage (i.e., stage 2) is

$$\vec{a}_2 = -g\hat{y} \quad \text{and} \quad v_{20} = v_1 \quad \text{so}$$

$$v_y = v_{1y} + a_2 t \quad \text{or} \quad 0 = v_{1y} - gt$$

Solving for t gives:

$$t = \frac{v_{1y}}{g} = \frac{152\ m/s}{9.80\ m/s^2} = 15.5\ s$$

→ however this is the time since t_1!

So $t_{MAX} = t_1 + t = 3.00\ s + 15.5\ s = 18.5\ s$

Now Δy_2 is the additional altitude that the rocket gains from h at the end of stage 1 to get to y_{MAX}, hence we use x_1, y_1, and t_1 as our initial conditions to get

$$\Delta y_2 = v_{1y} t + \tfrac{1}{2} a_z t^2 = v_{1y} t - \tfrac{1}{2} g t^2$$

$$= (152\ \tfrac{m}{s})(15.5\ s) - \tfrac{1}{2}(9.80\ \tfrac{m}{s^2})(15.5\ s)^2$$

$$= 2348\ m - 1174\ m = 1174\ m$$

So the maximum height above the ground is

$$y_{MAX} = h + \Delta y_2 = 347\ m + 1174\ m = 1521\ m$$

$$= \boxed{1521\ m}$$

We will refer to the time from t_1 until the rocket gets to y_{MAX} as

$$t_* = 15.5\ s$$

for the rest of this problem.

b) Total flight time:

We need to figure out how long it will take for the rocket to fall to the ground from y_{MAX}. Let's label this time as t_f, then

$$t_2 = t_* + t_f \quad \text{and} \quad t_{TOT} = t_0 + t_1 + t_2 = t_1 + t_* + t_f$$

STAGES

since the initial time $t_0 = 0$.

Let v_0 now represent the velocity when the rocket is at y_{MAX}, then define

$$\Delta y = y_{GROUND} - y_{MAX} = v_{0y} t_f - \frac{1}{2} g t_f^2$$

$v_{0y} = 0$ (top of trajectory), $y_{GROUND} = 0$,

$y_{max} = 1520\ m$, so

$$0 - 1520\ m = 0 - \frac{1}{2}\left(9.80\ \frac{m}{s^2}\right) t_f^2$$

$$\frac{1}{2}\left(9.80\ \frac{m}{s^2}\right) t_f^2 = 1520\ m$$

$$t_f = \sqrt{\frac{1520\ m \times 2}{9.80\ m/s^2}} = 17.6\ s$$

Finally,

$$t_{TOT} = t_1 + t_* + t_f = 3.00\ s + 15.5\ s + 17.6\ s$$

$$= \boxed{36.1\ s}$$

c) Horizontal range:

The horizontal range during free-fall from x_1 is

$$\Delta x_2 = v_{1x} t_2$$

where v_{1x} is the (initial) velocity of stage 2 (the free-fall stage) and t_2 (~~the~~ free fall time) is

$$t_2 = t_* + t_s = 15.5\,s + 17.6\,s = 33.1\,s$$

So

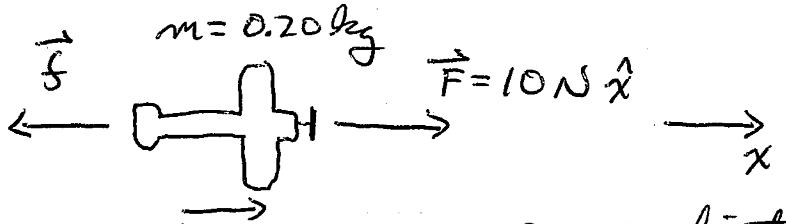
$$\Delta x_2 = (114\ m/s)(33.1\,s) = 3770\ m$$

Finally, the total horizontal range is

$$x_2 = x_1 + \Delta x_2 = 262\ m + 3770\ m$$

$$= \boxed{4032\ m/s}$$

16.



$\vec{a} = 2.0\,\frac{m}{s^2}\,\hat{x}$, f = air friction force

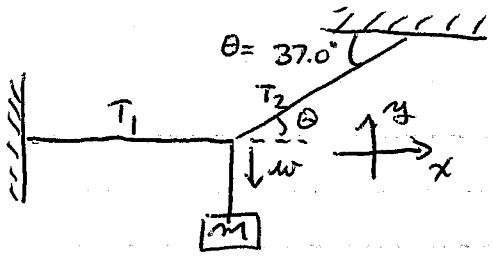
Using Newton's 2nd Law: $\sum F_x = ma$

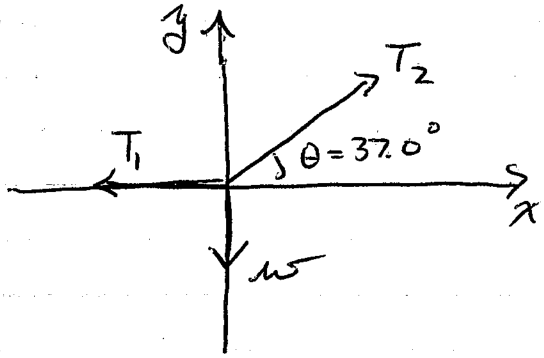
$$F - f = ma$$

$$f = F - ma = 10N - (0.20\,kg)(2.0\,\frac{m}{s^2})$$

$$= 10N - 0.4\,N = \boxed{9.6\,N}$$

17.





$w = mg = 600\,N$

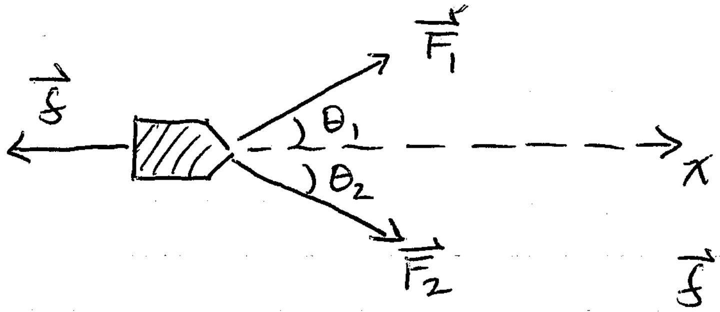
Equilibrium in effect: $\sum F_y = T_2 \sin\theta - w = 0$

$$T_2 = \frac{w}{\sin\theta} = \frac{600\,N}{\sin 37.0°} = \boxed{997\,N}$$ inclined cable

$$\sum F_x = T_2 \cos\theta - T_1 = 0$$

$$T_1 = T_2 \cos\theta = (997\,N)\cos 37.0° = \boxed{796\,N}$$ horizontal cable

18.



$|\vec{F}_1| = |\vec{F}_2| = 600. N$

$\theta_1 = 30.0°, \theta_2 = -30.0°$

$\vec{f}$ = resistive force

Since boat moves at constant velocity, $\vec{a}_{BOAT} = 0$.

$\therefore \sum \vec{F} = m\vec{a} = 0$;

$$\sum \vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{f} = 0$$

Only need to work in x-direction:

$$\sum F_x = F_1 \cos\theta_1 + F_2 \cos\theta_2 - f = 0$$

$$f = F_1 \cos\theta_1 + F_2 \cos\theta_2$$

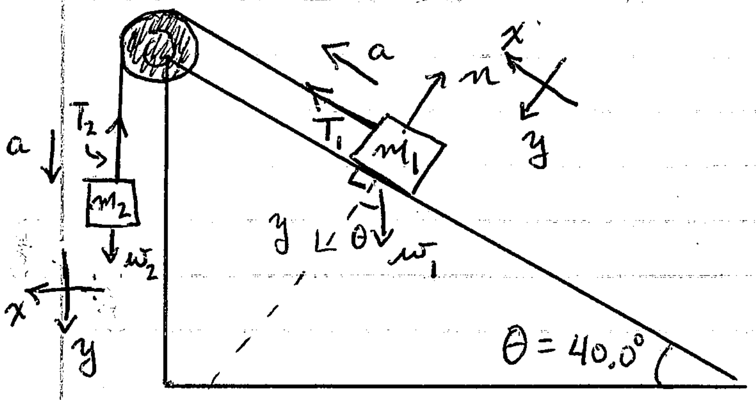
$$= (600 N) \cos 30.0° + (600 N) \cos(-30.0°)$$

$$= 520 N + 520 N = 1040 N$$

Since f is pointed in the negative x direction,

$$\boxed{\vec{f} = (-1040 N)\ \hat{x}}$$

19.



$m_1 = 5.00$ kg
$m_2 = 10.0$ kg

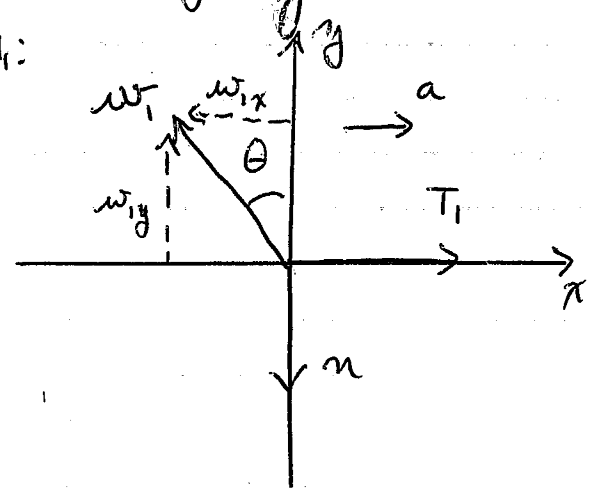
$m_1 < m_2$

$\theta = 40.0°$, $f_k = 0$

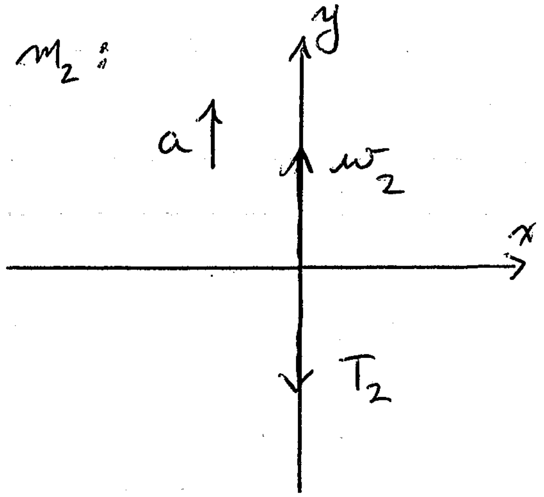
acc. 'a' is same magnitude for both masses.

Free-body diagrams:

m_1:



m_2:



Coordinates chosen such that 'a' points in + dir.

Assume that the string doesn't stretch, then
$|\vec{T}_1| = |\vec{T}_2| = T.$

Mass 1:

$$\sum F_x = T - w_1 \sin\theta = m_1 a \qquad (1)$$

$$\sum F_y = w_1 \cos\theta - n = 0 \qquad (2)$$

1-26

Mass 2:

$$\Sigma F_y = w_2 - T = m_2 a \qquad (3)$$

(no x-component in force equation)

$$w_1 = m_1 g = (5.00\ kg)(9.80\ \tfrac{m}{s^2}) = 49.0\ N$$

$$w_2 = m_2 g = (10.0\ kg)(9.80\ \tfrac{m}{s^2}) = 98.0\ N$$

Solve Eqs. (1) & (3) for "a" and subtract:

$$(1): \quad a = \frac{T - m_1 g \sin\theta}{m_1} = \frac{T}{m_1} - g\sin\theta \qquad (1^*)$$

$$(3): \quad a = \frac{m_2 g - T}{m_2} = g - \frac{T}{m_2} \qquad (3^*)$$

$$(1^*)-(3^*): \quad 0 = \frac{T}{m_1} - g\sin\theta - g + \frac{T}{m_2}$$

$$\frac{T}{m_1} + \frac{T}{m_2} = g(1+\sin\theta)$$

$$T\left(\frac{m_2}{m_1 m_2} + \frac{m_1}{m_1 m_2}\right) = g(1+\sin\theta)$$

$$\frac{m_1+m_2}{m_1 m_2} T = g(1+\sin\theta)$$

$$T = \frac{m_1 m_2}{m_1+m_2}\, g\,(1+\sin\theta)$$

$$= \frac{(50.0\ kg^2)}{15.0\ kg}(9.80\ \tfrac{m}{s^2})(1+\sin 40.0^\circ)$$

$$= \boxed{53.7\ N}$$

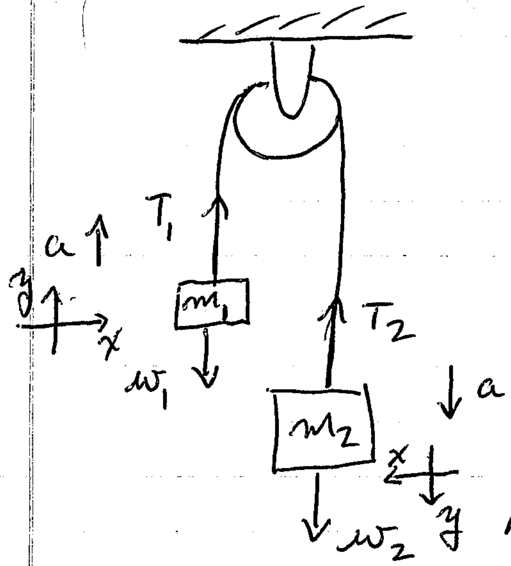
1-27

Use this in Eq. (3*):

$$a = g - \frac{T}{m_2} = 9.80\,\frac{m}{s^2} - \frac{53.7\,N}{10.0\,kg}$$

$$= \boxed{4.43\ m/s^2}$$

20.



$m_1 = 3.00$ kg $\quad w_1 = m_1 g$
$m_2 = 5.00$ kg $\quad w_2 = m_2 g$

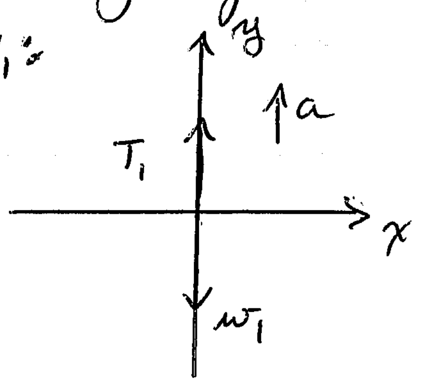
$m_2 > m_1$, so 'a' is in direction indicated and its magnitude will be the same for each mass

Assume string doesn't stretch:

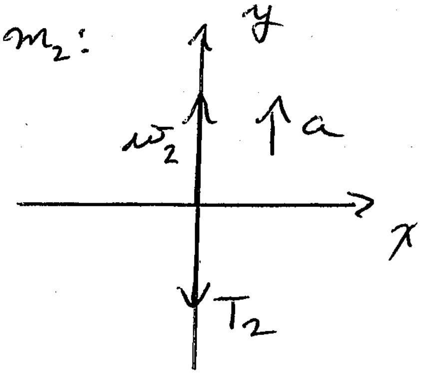
$$|\vec{T}_1| = |\vec{T}_2| = T$$

Free-body diagrams:

m_1:



m_2:



Mass 1: $\sum F_y = T - m_1 g = m_1 a \quad (1)$

Mass 2: $\sum F_y = m_2 g - T = m_2 a \quad (2)$

a) Find T:

$$a = \frac{T - m_1 g}{m_1} = \frac{T}{m_1} - g \quad (1^*)$$

$$a = \frac{m_2 g - T}{m_2} = g - \frac{T}{m_2} \quad (2^*)$$

$$(1^*)-(2^*): \quad 0 = \frac{T}{m_1} - g - g + \frac{T}{m_2}$$

$$\frac{T}{m_1} + \frac{T}{m_2} = g + g = 2g$$

$$T\left(\frac{m_2+m_1}{m_1 m_2}\right) = 2g$$

$$T = 2\frac{m_1 m_2}{m_1+m_2} g = 2\left(\frac{15.0\ kg^2}{8.00\ kg}\right)\left(9.80\ \frac{m}{s^2}\right)$$

$$= \boxed{36.8\ N}$$

b) Find acceleration (same for both):

$$T = m_1 a + m_1 g = m_1(a+g) \quad (1^{**})$$

$$T = m_2 g - m_2 a = m_2(g-a) \quad (2^{**})$$

$$(1^{**})-(2^{**}): \quad 0 = m_1(a+g) - m_2(g-a)$$

$$0 = m_1 a + m_1 g - m_2 g + m_2 a$$

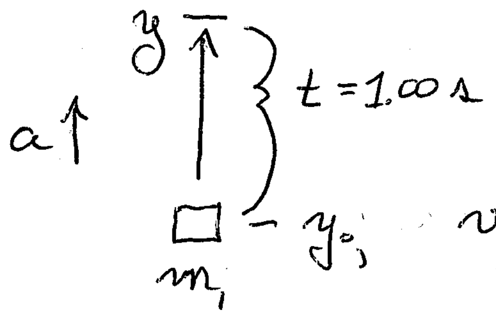
$$= a(m_1+m_2) + g(m_1-m_2)$$

$$a = -g\frac{(m_1-m_2)}{(m_1+m_2)} = \frac{m_2-m_1}{m_1+m_2} g$$

$$= \frac{2.00\ kg}{8.00\ kg}(9.80\ m/s^2) = \boxed{2.45\ m/s^2}$$

c) Find Δy (same for both) in 1 second:

Since $|\Delta y|$ will be the same for both masses, we will choose to work with m_1:



$v_{0y} = 0$

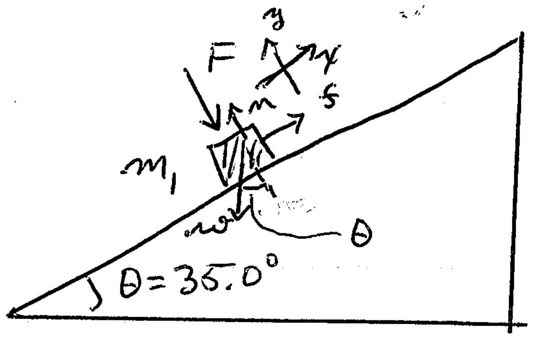
$$y = y_0 + v_{0y}t + \frac{1}{2}at^2$$

$$\Delta y = v_{0y}t + \frac{1}{2}at^2$$

$$= 0 + \frac{1}{2}\left(2.45\,\frac{m}{s^2}\right)(1.00\,s)^2$$

$$= \boxed{1.23\,m}$$

21.



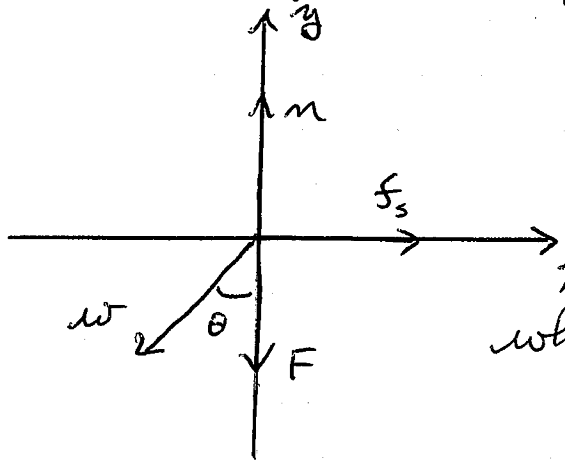
$\mu_s = 0.300$

$m_1 = 3.00\ kg$

$\theta = 35.0°$

Minimum F to prevent block from sliding:

Free-body diagram:



Equilibrium applies:

$\sum F_x = f_s - w \sin\theta = 0$

$\sum F_y = n - F - w\cos\theta = 0$

where, here, F is the minimum force to just keep mass from sliding and $w = mg$.

From y: $F = n - w\cos\theta$ (1)

From x: $f_s = \mu_s n = w \sin\theta$ (2)

so $n = \dfrac{w\sin\theta}{\mu_s} = \dfrac{mg\sin\theta}{\mu_s} = \dfrac{(3.00\,kg)(9.80\,\frac{m}{s^2})\sin 35.0°}{0.300}$

$= 56.2\ N$

Plug into (1) gives:

$F = 56.2\,N - (3.00\,kg)(9.80\,\frac{m}{s^2})\cos 35.0° = \boxed{32.1\ N}$