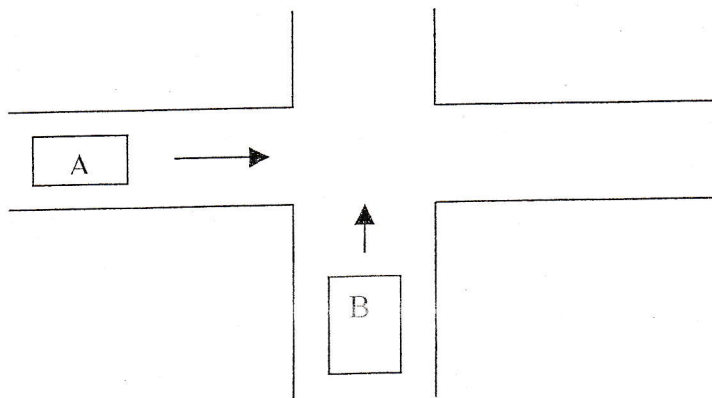


Key

Physics 122/121
Handout - Relative Velocity #1

- Two passenger trains are passing each other on adjacent tracks. Train A is moving east with a speed of 13 m/s, and train B is traveling west with a speed of 28 m/s.
 - What is the velocity of train A as seen by the passengers on train B? (41 m/s, east)
 - What is the velocity of train B as seen by the passengers on train A? (41 m/s, west)
- Two trains A and B are traveling in the same direction although train A is 186 m behind train B. The speed of A is 24.4 m/s and the speed of B is 18.6 m/s. How much time does it take A to catch B? (32.1 s)
- The escalator that leads down into a subway station has a length of 30 m and a speed of 1.8 m/s relative to the ground. A student is coming out of the station by running in the wrong direction on this escalator. The local record for this trick is 11 s. Relative to the escalator, what speed must the student exceed in order to beat the record? (4.5 m/s)
- The diagram shows two cars approaching an intersection along perpendicular roads. The velocity of A relative to the ground is 25.0 m/s, E and the velocity of B relative to the ground is 15.8 m/s, N. Find the velocity of A relative to B. (29.6 m/s, 32.3° S of E)



- A swimmer capable of swimming at a speed of 1.4 m/s in still water, starts to swim directly across a 2.8 km wide river. However, the current is 0.91 m/s and carries the swimmer downstream.
 - How long does it take the swimmer to cross the river? (2.0×10^3 s)
 - How far downstream will the swimmer be upon reaching the other side of the river? (1.8×10^3 m)

Physics 122/121
 Handout - Relative Velocity #1

#1. $\vec{v}_{AG} = 13 \text{ m/s, E}$
 $\vec{v}_{BG} = 28 \text{ m/s, W}$

a) $\vec{v}_{AB} = \vec{v}_{AG} + \vec{v}_{GB}$
 $\vec{v}_{AB} = \vec{v}_{AG} - \vec{v}_{BG}$ \vec{v}_{AB} is 41 m/s, E
 $\vec{v}_{AB} = 13 - (-28)$
 $\vec{v}_{AB} = 41 \text{ m/s}$

b) $\vec{v}_{BA} = \vec{v}_{BG} + \vec{v}_{GA}$
 $\vec{v}_{BA} = \vec{v}_{BG} - \vec{v}_{AG}$ \vec{v}_{BA} is 41 m/s, W
 $\vec{v}_{BA} = (-28) - (13)$
 $\vec{v}_{BA} = -41 \text{ m/s}$

#2. \rightarrow \rightarrow
A B
 $\vec{v}_{AG} = +24.4 \text{ m/s}$ $\vec{v}_{BG} = +18.6 \text{ m/s}$

$\vec{v}_{AB} = \vec{v}_{AG} + \vec{v}_{BG}$
 $\vec{v}_{AB} = \vec{v}_{AG} - \vec{v}_{GB}$
 $\vec{v}_{AB} = 24.4 - (18.6)$
 $\vec{v}_{AB} = 5.80 \text{ m/s}$

clt takes A
 32.1 s to reach
 B

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

$t = \frac{d}{v} = \frac{186 \text{ m}}{5.80 \text{ m/s}} = 32.1 \text{ s}$

3

$$\vec{v}_{se} = ?$$

$$\vec{v}_{sg} = \frac{30.0 \text{ m}}{11 \text{ s}} = 2.73 \text{ m/s}$$

$$\vec{v}_{eg} = -1.8 \text{ m/s}$$

$$\vec{v}_{se} = \vec{v}_{sg} + \vec{v}_{ge}$$

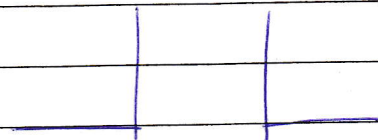
$$\vec{v}_{se} = \vec{v}_{sg} - \vec{v}_{ge}$$

$$\vec{v}_{se} = 2.73 - (-1.8)$$

$$\vec{v}_{se} = +4.5 \text{ m/s}$$

The speed of the student relative to the accelerator must exceed 4.5 m/s.

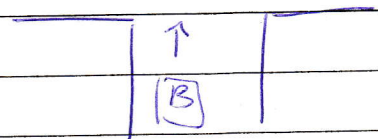
4



$$\vec{v}_{AB} = +25.0 \text{ m/s}$$

$$\vec{v}_{Bg} = +15.8 \text{ m/s}$$

A →

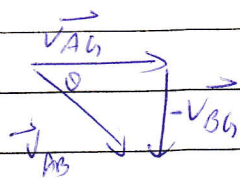


$$\vec{v}_{AB} = \vec{v}_{Ag} + \vec{v}_{gB}$$

$$\vec{v}_{AB} = \vec{v}_{Ag} - \vec{v}_{Bg}$$

$$v_{AB} = \sqrt{(25.0)^2 + (15.8)^2}$$

$$v_{AB} = 29.6 \text{ m/s}$$

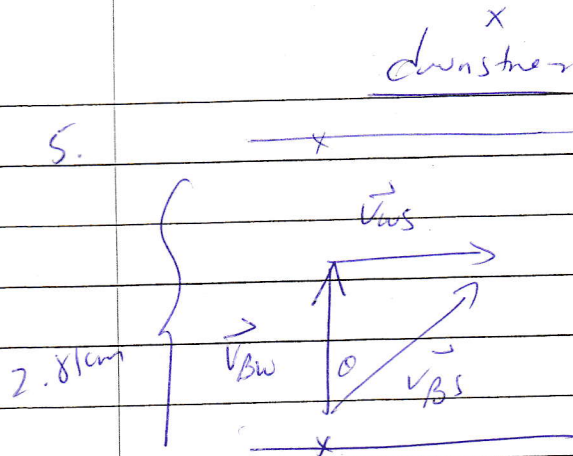


$$\tan \theta = \frac{15.8}{25.0}$$

$$\theta = 32.3^\circ$$

The vel. of A rel. to B is 29.6 m/s, 32.3° S of E.

5.



$$v_{BW} = 1.4 \text{ m/s (still H}_2\text{O)}$$

$$v_{ws} = 0.91 \text{ m/s}$$

$$\text{width} = 2.81 \text{ cm} = 2.8 \times 10^{-3} \text{ m}$$

$$a) \quad v = \frac{d}{t}$$

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

$$t = \frac{2.8 \times 10^{-3} \text{ m}}{1.4 \text{ s}}$$

$$t = 2.0 \times 10^{-3} \text{ s}$$

Let time $2.0 \times 10^{-3} \text{ s}$.

$$b) \quad v = \frac{x}{t}$$

$$x = v_{ws} t$$

$$x = (0.91)(2.0 \times 10^{-3})$$

$$x = 1.8 \times 10^{-3} \text{ m}$$

The swimmer will be $1.8 \times 10^{-3} \text{ m}$ downstream.

Key

Physics 20

Chapter 2 Worksheet #2

Answer the following questions on a separate sheet. Make sure to follow all rules for setting up a question, sig digs, and scientific notation when appropriate. Answers are in brackets and italics after each question.

1. **Explain** what a "vector" is, and give specifics of how it is drawn.
2. You are pushing on a lawnmower so that the handle makes a 40° angle with the ground. The force you are exerting is 150 N.
 - a) **Determine** the components of the force horizontally and vertically. (*Horz = $1.1e2N$, Vert = $96N$*)
 - b) You are thinking about changing the handle position so that it makes an angle of 30° to the ground. **Prove** that this will help you move the mower more efficiently. (*Horz = $1.3e2 N$, so more force being used to actually push forward.*)
3. You are taking an introductory course in aircraft so that you can eventually take flying lessons. In the course they are showing you how a helicopter can be blown off course if the pilot does not take the wind speed into account. The foolish pilot in the example is trying to fly West to a town that is 220 km away. He is flying helicopter that can move at 85 km/h in still air. He is flying due West, without taking into account that there is a 28 km/h [N] wind.
 - a) **Determine** the pilot's resultant velocity. (*$89 \text{ km/h [W}18^\circ\text{N]$*)
 - b) **Determine** how long the pilot *thinks* he should be in the air to reach his destination. (*$2.6h$*)
 - c) After the time he believes he should be in the air for, he lands. **Determine** how far North from his target he is when he lands. (*72 km [N]*)
4. The airspeed of a small plane is 200 km/h. The wind speed is 50.0 km/h [E]. **Determine** the velocity of the plane relative to the ground if the pilot keeps the plane pointing in each of the following directions.
 - a) East (*250 km/h [E]*)
 - b) West (*150 km/h [W]*)
 - c) North (*$206 \text{ km/h [N}14.0^\circ\text{E]}$*)
 - d) North 40° East (*$2.4e2 \text{ km/h [E}41^\circ\text{N]}$*)
 - e) West 16° South
5. A swimmer can swim at a speed of 1.80 m/s in still water. If the current in a river 200 m wide is 1.00m/s [E], and the swimmer starts on the south bank and swims so that she is always pointing directly across the river, **determine** each of the following.
 - a) The swimmer's resultant velocity, relative to the river bank. (*$2.06 \text{ m/s [N}29^\circ\text{E]}$*)
 - b) How long she will take to reach the north shore. (*$111s$*)
 - c) How far downstream she will land (from the point opposite her starting point). (*111 m [E]*)
6. A swimmer on the south shore of a river wishes to swim to a dock directly north of her starting point. Her maximum swimming speed in still water is 4.0 km/h and there is a current in the river flowing 2.5km/h towards the west.
 - a) **Determine** the direction in which she must swim so she goes straight north across the river. (*$[N39^\circ\text{E}]$*)
 - b) If the river is 2.0 km wide, **determine** how long it takes her to cross. (*$0.65 \text{ h or } 39 \text{ min}$*)

Physics 20 - C2 Worksheet

4. $v_{pa} = 200 \text{ km/h}$
 $\vec{v}_{ag} = 50.0 \text{ km/h, E}$

a) $\vec{v}_{pg} = ?$ if \vec{v}_{pa} is east

$$\vec{v}_{pg} = \vec{v}_{pa} + \vec{v}_{ag}$$

$$\vec{v}_{pg} = (200) + (50.0)$$

$$\vec{v}_{pg} = 250 \text{ km/h}$$

$$\vec{v}_{pg} = 250 \text{ km/h, E}$$

b) $\vec{v}_{pg} = ?$ if \vec{v}_{pa} is west

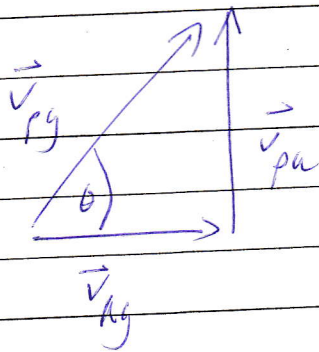
$$\vec{v}_{pg} = \vec{v}_{pa} + \vec{v}_{ag}$$

$$\vec{v}_{pg} = (-200) + (50.0)$$

$$\vec{v}_{pg} = -150 \text{ km/h}$$

$$\vec{v}_{pg} = 150 \text{ km/h, W}$$

c) $\vec{v}_{pg} = ?$ if \vec{v}_{pa} is north



$$v_{pg} = \sqrt{v_{pa}^2 + v_{ag}^2}$$

$$v_{pg} = \sqrt{(200)^2 + (50.0)^2}$$

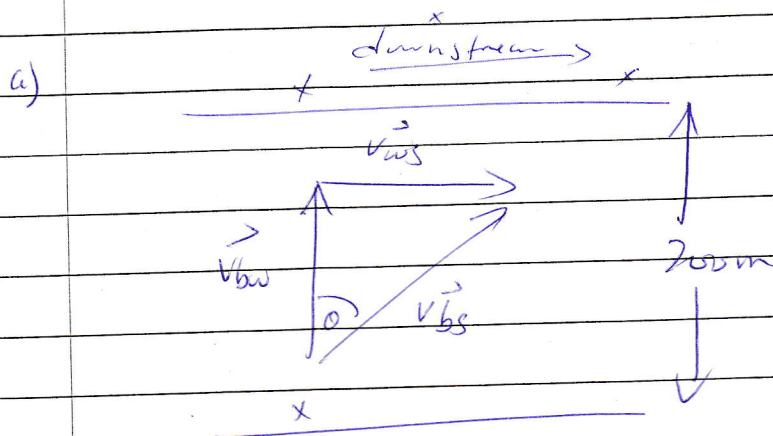
$$v_{pg} = 206 \text{ km/h}$$

$$\tan \theta = \frac{200}{50.0}$$

$$\theta = 76.0^\circ$$

$$\vec{v}_{pg} = 206 \text{ km/h, } 76.0^\circ \text{ N of E}$$

5. $v_{bw} = 1.80 \text{ m/s}$ (still water) b-body
 $\vec{v}_{ws} = 1.00 \text{ m/s}, \vec{E}$



$v_{bs} = \sqrt{(1.80)^2 + (1.00)^2}$ $\tan \theta = \frac{1.00}{1.80}$
 $v_{bs} = 2.06 \text{ m/s}$ $\theta = 29.1^\circ$

The velocity of the swimmer relative to the shore is 2.06 m/s , 29.1°

b) $v_{bw} = \frac{d}{t}$

$t = \frac{d}{v_{bw}}$

v_{bw}

$t = \frac{200 \text{ m}}{1.80 \text{ m/s}}$

$t = 111 \text{ s}$

$t = 111 \text{ s}$

It takes 111 s.

c) $v_{ws} = \frac{x}{t}$

$x = v_{ws} t$

$x = (1.00)(111)$

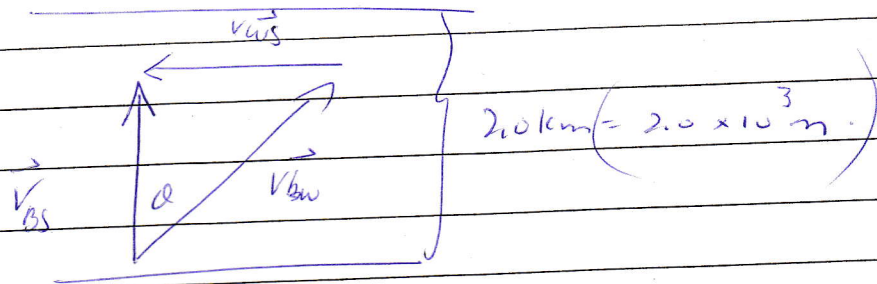
$x = 111 \text{ m}$

She will be 111 m

downstream.

6. $v_{bw} = 4.0 \text{ km/h}$
 $v_{ws} = 2.5 \text{ km/h, west}$

b-body



a) $\sin \theta = \frac{2.5}{4.0}$ She must swim 39° E of N.
 $\theta = 39^\circ$

b) $v_{bs} = \frac{d}{t}$ $v_{bs} = \sqrt{(4.0)^2 - (2.5)^2}$
 $v_{bs} = 3.12 \text{ km/h}$

$$t = \frac{d}{v_{bs}}$$

$$t = \frac{2.0 \text{ km}}{3.12 \text{ km/h}}$$

$$t = 0.64 \text{ h or } 38 \text{ min.}$$

Let takes 0.64 h.

Physics 122/121
Handout: Relative Velocity – More Practice #3

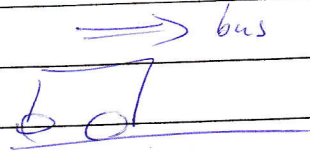
Key

1. A bus is traveling at 45.9 mph (miles per hour) while a man walks down the aisle. If the man's speed relative to the ground is 41.4 mph, is he walking towards the front or back of the bus? (towards the back)
2. A bus is traveling at 44 km/h while a lady walks to the front at a speed of 3.8 km/h relative to the bus floor. What is her speed relative to the ground? (47.8 km/h)
3. A boat aims straight for the ~~opposite bank of a 119.8 m wide river~~ which is flowing with a speed of 1.9 km/h. ~~If the boat reaches the opposite side 185.1 m downstream, what is the speed of the boat relative to the water?~~ (2.3 km/h)
1.2
4. A boat which travels at 4.6 km/h relative to the water aims straight for the opposite bank of a river. If the average river speed is 7.8 km/h and the boat is 138 m downstream when it reaches the opposite side, how wide is the river? (81.4 m)
5. A bus is traveling along a straight highway at a constant 55 mph. A person sitting at rest on the bus fires a dart gun that has muzzle velocity of 45 mph toward the back of the bus. Find the velocity of the dart relative to the road. (10 mph in the direction in which the bus is traveling).
6. A swimmer can swim at a speed of 0.70 m/s with respect to the water. She wants to cross a river which is 50 m wide and has a current of 0.50 m/s.
 - a) If she wishes to land on the other bank at a point directly across the river from her starting point, in what direction must she swim? (46° upstream from the direction "straight across")
 - b) If, she instead decides to cross in the shortest possible time, in what direction must she swim? How far downstream will she be when she lands? (35.7 m)

Physics 122 / 121

Handout: Relative Velocity - More Practice #3

1. $v_{Bg} = 45.9 \text{ mph}$
 $v_{mg} = 41.4 \text{ mph}$
 $\vec{v}_{mb} = ?$



$$\vec{v}_{mb} = \vec{v}_{mg} + \vec{v}_{gb}$$

$$\vec{v}_{mb} = \vec{v}_{mg} - \vec{v}_{bg}$$

$$\vec{v}_{mb} = 41.4 - 45.9$$

$$\vec{v}_{mb} = -4.5 \text{ mph}$$

He is walking
towards the back
of the bus

2. $\vec{v}_{bg} = 44 \text{ km/h}$
 $\vec{v}_{lb} = 3.8 \text{ km/h}$
 $\vec{v}_{lg} = ?$

$$\vec{v}_{lg} = \vec{v}_{lb} + \vec{v}_{bg}$$

$$\vec{v}_{lg} = 3.8 + 44$$

$$\vec{v}_{lg} = 47.8 \text{ km/h} \Rightarrow 48 \text{ km/h}$$

Her speed relative
to the ground is
48 km/h.

3. Omit

4. $v_{bw} = 4.6 \text{ km/h}$
 $v_{ws} = 7.8 \text{ km/h}$
width = ?

0.138 km

downstream = 138 m

$v_{ws} = \frac{d}{t}$ $v_{bw} = \frac{x}{t}$

$t = \frac{d}{v_{ws}}$ $x = v_{bw} t$

$t = \frac{0.138 \text{ km}}{7.8 \text{ km/h}}$ $x = (4.6)(0.0177)$

$t = 0.0177 \text{ h}$ $x = 0.081 \text{ km}$

The river is 0.081 km wide or 81 m wide.

5. $\vec{v}_{br} = 55 \text{ mph}$ (r-road) \vec{v}_{br}

$\vec{v}_{db} = -45 \text{ mph}$

$\vec{v}_{dr} = ?$

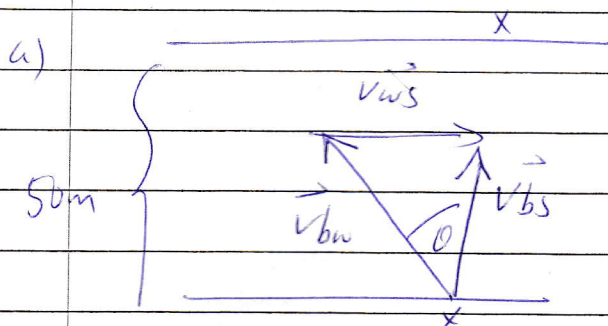
$$\vec{v}_{dr} = \vec{v}_{db} + \vec{v}_{br}$$

$$\vec{v}_{dr} = -45 + 55$$

$$\vec{v}_{dr} = 10 \text{ mph}$$

The velocity of the dirt relative to the road is 10 mph in the direction in which the bus is traveling.

6. $v_{bw} = 0.70 \text{ m/s}$
 $v_{ws} = 0.50 \text{ m/s}$



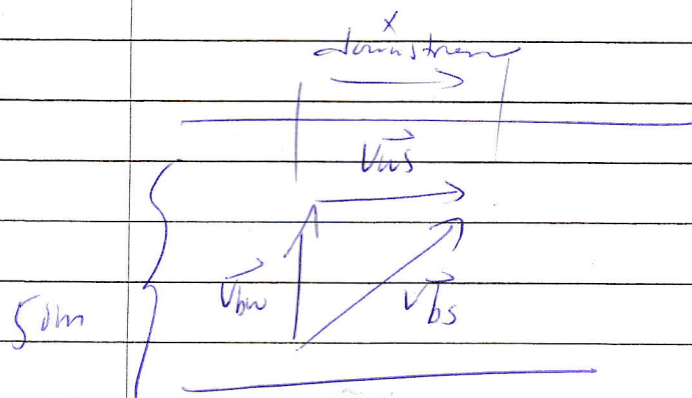
$$\sin \theta = \frac{v_{ws}}{v_{bw}}$$

$$\sin \theta = \frac{0.50}{0.70}$$

$$\theta = 46^\circ$$

She must swim 46° W of N.

b) She should swim northward.



$$v_{bw} = \frac{50 \text{ m}}{t}$$

$$t = \frac{50 \text{ m}}{0.70 \text{ s}}$$

$$t = 71.4 \text{ s (time to cross)}$$

She will be
36 m downstream.

$$v_{ws} = \frac{x}{t}$$

$$x = (0.50)(71.4)$$

$$x = 36 \text{ m}$$

Physics 122/121
Handout: Review – Relative Velocity #4

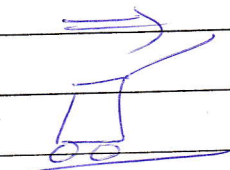
Key

1. Rafi is pulling a toy wagon through the neighborhood at a speed of 0.75 m/s. A caterpillar in the wagon is crawling toward the rear of the wagon at a rate of 2.0 cm/s. What is the caterpillar's speed relative to the ground? (0.73 m/s)
2. A boat is rowed directly upriver at a speed of 2.5 m/s relative to the water. Viewers on the shore see that the boat is moving at only 0.5 m/s relative to the shore. What is the speed of the river? Is it moving with or against the boat? (2.0 m/s; against the boat)
3. An airplane flies due north at 150 km/h relative to the air. There is a wind blowing at 75 km/h to the east relative to the ground. What is the plane's velocity relative to the ground? (1.7×10^2 km/h, 63° N of E)
4. A swimmer can swim at a speed of 1.28 m/s in still water. If the current in a river 297 m wide is 1.47 m/s east and the swimmer starts on the south bank and swims so that she is always headed directly across the river, how many meters downstream will she land (from the point opposite her starting point). (342 m)
5. The pilot of a light plane heads due north at an airspeed of 180 km/h. A wind is blowing from the west at 60.0 km/h. What is the plane's velocity with respect to the ground? (190 km/h, 71.6° N of E)
6. A canoeist paddles south across a river at 3.0 m/s and is always at right angles to the river flow. The river flows east at 4.0 m/s and is 100 m wide.
 - a) What is the velocity of the canoe relative to the riverbank? (5.0 m/s, 37° S of E)
 - b) Calculate the time taken to cross the river. (33 s)
 - c) How far downstream is the landing point from the launching point? (1.3×10^2 m)

Physics 122/121

Handout - Review - Relative Vel. #4

1. $\vec{v}_{wg} = 0.75 \text{ m/s}$
 $\vec{v}_{cw} = \frac{-2.0 \text{ cm}}{5} = \frac{-0.020 \text{ m}}{5}$

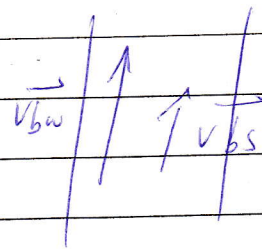


$\vec{v}_{cg} = ?$

$\vec{v}_{cg} = \vec{v}_{cw} + \vec{v}_{wg}$
 $\vec{v}_{cg} = -0.020 + 0.75$
 $\vec{v}_{cg} = +0.73 \text{ m/s}$

The caterpillar's speed relative to the ground is 0.73 m/s.

2. $\vec{v}_{bw} = +2.5 \text{ m/s}$
 $\vec{v}_{bs} = +0.5 \text{ m/s}$

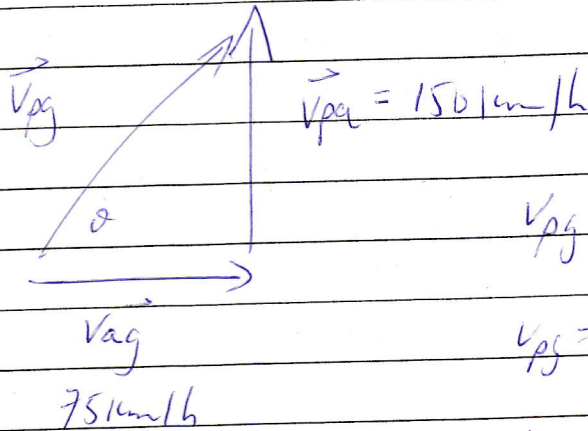


$\vec{v}_{ws} = ?$

$\vec{v}_{ws} = \vec{v}_{bw} + \vec{v}_{bs}$
 $\vec{v}_{ws} = -2.5 + 0.5$
 $\vec{v}_{ws} = -2.0 \text{ m/s}$

The speed of the river is 2.0 m/s

3.



$$V_{pg} = \sqrt{V_{pa}^2 + V_{ag}^2}$$

$$V_{pg} = \sqrt{(150)^2 + (75)^2}$$

$$V_{pg} = 1.7 \times 10^2 \text{ km/h}$$

The plane's velocity relative to the ground is $1.7 \times 10^2 \text{ km/h}$, 63° N of E.

$$\tan \theta = \frac{150}{75}$$

$$\theta = 63^\circ$$

4.

$$V_{bw} = 1.28 \text{ m/s}$$

$$\vec{V}_{ws} = 1.47 \text{ m/s, E}$$

$$V_{bw} = \frac{297 \text{ m}}{t}$$

$$t = \frac{297 \text{ m}}{1.28 \text{ m/s}}$$

$$t = 232.0 \text{ s}$$

$$t = 232.0 \text{ s}$$

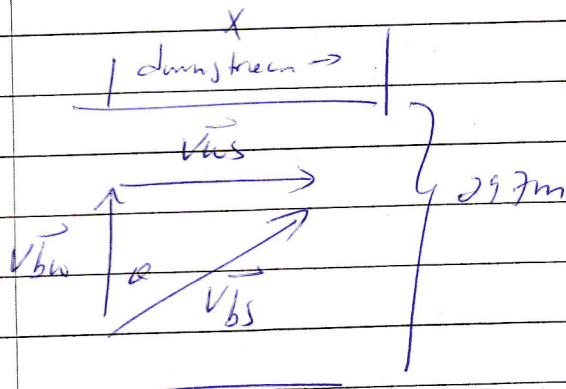
$$V_{ws} = \frac{x}{t}$$

$$x = V_{ws} t$$

$$x = (1.47)(232.0)$$

$$x = 341 \text{ m}$$

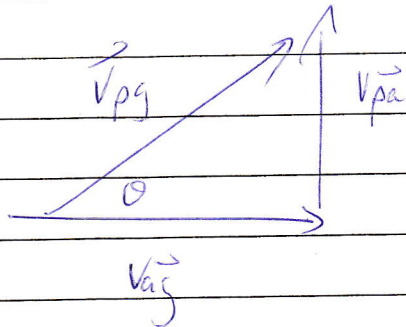
She will land 341 m downstream.



5. $\vec{v}_{pa} = 180 \text{ km/h, N}$
 $\vec{v}_{ag} = 60.0 \text{ km/h, E}$
 $\vec{v}_{pg} = ?$

$$v_{pg} = \sqrt{(180)^2 + (60.0)^2}$$

$$v_{pg} = 190 \text{ km/h}$$

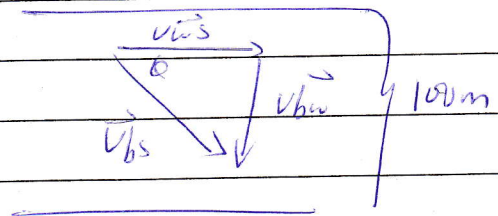


$$\tan \theta = \frac{180}{60.0}$$

$$\theta = 71.6^\circ$$

The plane's velocity with respect to the ground is 71.6° N of E.

6. $\vec{v}_{bw} = 3.0 \text{ m/s, S}$
 $\vec{v}_{ws} = 4.0 \text{ m/s, E}$



a) $v_{bs} = \sqrt{(3.0)^2 + (4.0)^2}$
 $v_{bs} = 5.0 \text{ m/s}$

$$\tan \theta = \frac{3.0}{4.0}$$

$$\theta = 37^\circ$$

The velocity of the canoe relative to the river bank is $5.0 \text{ m/s, } 37^\circ$ S of E.

b) $t = \frac{d}{v_{bw}} = \frac{100}{3.0} = 33.5$ s at take 33.5.

c) $x = v_{ws} t = (4.0)(33) = 1.3 \times 10^2 \text{ m}$

The landing point is $1.3 \times 10^2 \text{ m}$ downstream.