SPH4U UNIVERSITY PHYSICS

DYNAMICS

- Relative Motion (P.44-49)

Relative Motion

Suppose that you are flying in an airplane at a constant velocity south. How would you describe the view? At first, the answer might seem simple and you would describe the clouds and the ground. After a little thought, you would realize that you can see much more. From the point of view of the plane, the ground and the clouds appear to be moving north and the plane appears to be stationary. However, from the point of view of an observer on the ground, the plane is moving south, the ground is stationary, and the clouds are moving with the wind.

September 12, 2012 4U1 - Relative Motion 1

Relative Velocity

The airplane scenario is an example of relative motion. The pilot and passengers in the plane are in one frame of reference, and the observer on the ground is in another frame of reference. The velocity of an object relative to a specific frame of reference is called ***relative velocity****. This term is useful when we study situations that involve at least two frames of reference. Such situations occur for passengers walking about in a moving train, for watercraft travelling on a flowing river, and for aircraft flying when there is wind blowing relative to the ground.*

RELATIVE VELOCITY

- velocity of an object relative to a specific frame of reference

September 12, 2012 4U1 - Relative Motion 2

Relative Velocity

NOTE!

To analyze relative velocity in more than one frame of reference, we use the symbol for relative velocity with two subscripts in capital letters. The first subscript represents the object whose velocity is stated relative to the object represented by the second subscript. In other words, the second subscript is the frame of reference (see below).

$$\vec{v}_{CW} = \text{velocity of the canoe relative to the water}$$

Relative Velocity

For example, if P is a plane travelling at 490 km/h[W] relative to Earth's frame of reference, E, then v_{PE} = 490 km/h[W]. If we consider another frame of reference, such as the wind or air, A, affecting the plane's motion, then v_{PA} is the velocity of the plane relative to the air and v_{AE} is the velocity of the air relative to Earth. The vectors v_{PA} and v_{AE} are related to v_{PE} using the following relative velocity equation:

$$\vec{v}_{PE} = \vec{v}_{PA} + \vec{v}_{AE}$$

NOTE!

*Air navigators have terms for some of the key concepts of relative velocity. **Air speed** is the speed of a plane relative to the air (v_{PA}). **Wind speed** is the speed of the air relative to Earth (v_{AE}). **Ground speed** is the speed of the plane relative to Earth (v_{PE}).*

Relative Velocity

This equation applies whether the motion is in one, two, or three dimensions. For example, consider the one-dimensional situation in which the wind and the plane are both moving eastward. If the plane's velocity relative to the air is 430 km/h[E], and the air's velocity relative to the ground is 90 km/h[E], the velocity of the plane relative to the ground is:

$$\begin{aligned}\vec{v}_{PE} &= \vec{v}_{PA} + \vec{v}_{AE}\\ &= 430\text{ km/h[E]} + 90\text{ km/h[E]}\\ \vec{v}_{PE} &= 520\text{ km/h[E]}\end{aligned}$$

Relative Velocity

NOTE!

Before looking at relative velocity in two dimensions, make sure you understand the pattern of the subscripts used in any relative velocity equation. As shown below, the left side of the equation has a single relative velocity, while the right side has the vector addition of two or more relative velocities. Note that the "outside" and the "inside" subscripts on the right side are in the same order as the subscripts on the left side.

$$\vec{v}_{PE} = \vec{v}_{PA} + \vec{v}_{AE} \qquad \vec{v}_{DG} = \vec{v}_{DE} + \vec{v}_{EF} + \vec{v}_{FG}$$

Relative Velocity

PRACTICE

1. A cruise ship is moving with a velocity of 2.8 m/s[fwd] relative to the water. A group of tourists walks on the deck with a velocity of 1.1 m/s relative to the deck. Determine the velocity of the tourists relative to the water (v_{TW}) if they are walking toward:
   (a) the bow (i.e. the front of the ship) Hint: v_{TS} = 1.1 m/s[fwd]

   (a) $v_{TW} = v_{TS} + v_{SW}$
   = 3.9 m/s[fwd]

Relative Velocity

PRACTICE

1. A cruise ship is moving with a velocity of 2.8 m/s[fwd] relative to the water. A group of tourists walks on the deck with a velocity of 1.1 m/s relative to the deck. Determine the velocity of the tourists relative to the water (v_{TW}) if they are walking toward:
   (b) the stern (i.e. the rear of the ship)

   (b) v_{TW} = 1.7 m/s[fwd]

Relative Velocity

PRACTICE

1. A cruise ship is moving with a velocity of 2.8 m/s[fwd] relative to the water. A group of tourists walks on the deck with a velocity of 1.1 m/s relative to the deck. Determine the velocity of the tourists relative to the water (v_{TW}) if they are walking toward:
   (c) the starboard (i.e. the right side of the ship as you face the bow)

   (c) v_{TW} = 3.0 m/s[21° right of fwd]

September 12, 2012 4U1 - Relative Motion 9

Relative Velocity

PRACTICE

2. A canoeist, capable of travelling at a speed of 4.5 m/s in still water, is crossing a river that is flowing with a velocity of 3.2 m/s[E]. The river is 220 m wide.
   (a) If the canoe is aimed northward, what is the velocity of the canoe relative to the shore?

   (a) $v_{CS} = v_{CW} + v_{WS}$
   = 5.5 m/s[N35°E]

September 12, 2012 4U1 - Relative Motion 10

Relative Velocity

PRACTICE

2. A canoeist, capable of travelling at a speed of 4.5 m/s in still water, is crossing a river that is flowing with a velocity of 3.2 m/s[E]. The river is 220 m wide.
   (b) How long does it take the canoe to cross the river?

   (b) t = 49 s

September 12, 2012 4U1 - Relative Motion 11

Relative Velocity

PRACTICE

2. A canoeist, capable of travelling at a speed of 4.5 m/s in still water, is crossing a river that is flowing with a velocity of 3.2 m/s[E]. The river is 220 m wide.
   (c) How far downstream does the canoe land?

   (c) d = 160 m[E]

September 12, 2012 4U1 - Relative Motion 12

Relative Velocity

PRACTICE

2. A canoeist, capable of travelling at a speed of 4.5 m/s in still water, is crossing a river that is flowing with a velocity of 3.2 m/s[E]. The river is 220 m wide.
   (d) If the canoeist wanted to land directly across from the starting position, at what angle should the canoe be aimed?

   (d) [N45°W] ☜ this value was calculated, not "assumed"

September 12, 2012 4U1 - Relative Motion 13

Relative Velocity

PRACTICE

3. An airplane flies due north over Sudbury with a velocity relative to the air of 235 km/h and with a wind velocity of 65.0 km/h[NE]. Calculate the speed and direction of the airplane.

   v_{PE} = 285 km/h[N9.3°E]

September 12, 2012 4U1 - Relative Motion 14

✔ Check Your Learning

TEXTBOOK

P.48 Q.3-7 (Practice)