3.3 Relative Velocities

SECTION OUTCOMES

- Describe the motion of an object that is in a moving medium using velocity vectors.
- Analyze quantitatively, the motion of an object relative to different reference frames.

KEY TERM

- relative velocity

Figure 3.8 The dog is moving relative to the water, and the water is moving relative to the river bank. How would you describe the dog's velocity relative to the river bank?

Have you ever been stopped at a stoplight and suddenly felt that you were starting to roll backward? Your immediate instinct was to slam on the brakes, but then you realized that you were not moving after all. You sheepishly realized that, in fact, the car beside you was creeping forward. Your mind had been tricked. Subconsciously, you assumed that the car beside you had remained stopped and that your car was moving backward. Indeed, you *were* moving, but not in the way in which your instincts were telling you. You were moving backward relative to the car beside you, because the other car was moving forward relative to the ground. Relative motion can be deceiving. The dog in the photograph may think that the river bank is moving sideways while he is swimming directly across the river. Is it?

Relative Velocity

Vector addition is a critical tool in calculating **relative velocities**. You have discovered that it is necessary to define a reference frame to describe any velocity. How do you relate velocities in two different reference frames? For example, an aviator must use the ground as a frame of reference to plot an airplane trip. However, when the plane is airborne, the air itself is moving relative to the ground, carrying the plane with it. So the aviator must account for both the motion of the plane relative to the air and the air relative to the ground. By defining velocity vectors for the plane relative to the air and for the air relative to the ground, the aviator can use

COURSE CHALLENGE: SPACE-BASED POWER

Staying in Orbit

Investigate the question, “Are geosynchronous satellites ever in the shade?” Design a quick lab idea to help you solve this problem.

vector addition to calculate the velocity of the plane relative to the ground, the critical piece of information.

An understanding of relative velocities is not a new problem. Imagine sailing on the high seas on a ship such as the one in Figure 3.9, in the days before communication technology was highly developed. Understanding wind and ocean currents was critical for navigation. The following model problems show you how to perform such calculations.

Figure 3.9 The lives of early sailors depended on their ability to accurately predict and control the motion of their ships, without any modern technology.

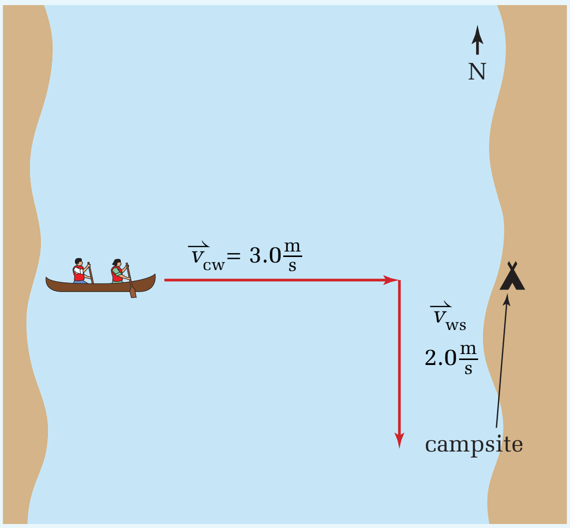
PHYSICS FILE

Nearly everyone has heard of Einstein's theory of relativity, but very few people understand it. According to the theory, relative velocities, as well as lengths of objects and time intervals, would appear to be very strange if you could travel close to the speed of light. For example, imagine that a train travelling close to the speed of light is passing through a short tunnel. An observer, who is stationary relative to the ground, would see the last car disappear into the tunnel before seeing the engine come out the other end. An observer on the train would perceive that the engine was leaving one end of the tunnel before the last car entered the other end. Now that's relativity!

MODEL PROBLEMS

Calculating Relative Velocities

1. A canoeist is planning to paddle to a campsite directly across a river that is 624 m wide. The velocity of the river is 2.0 m/s[S]. In still water, the canoeist can paddle at a speed of 3.0 m/s. If the canoeist points her canoe straight across the river, toward the east: (a) How long will it take her to reach the other river bank? (b) Where will she land relative to the campsite? (c) What is the velocity of the canoe relative to the point on the river bank, where she left?



Frame the Problem

- Make a sketch of the situation described in the problem.
- The *canoe* is *moving* relative to the *river*.

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- The *river* is *moving* relative to the *shore*.
- The *motion* of the *river* toward the south will *not* affect the *eastward motion* of the canoe.
- While the canoeist is *paddling east* across the river, the river is *carrying the canoe* downstream [S] with the current.
- The vector sum of the velocity of the *canoe relative* to the *water* and the *water* relative to the *shore* is the velocity of the *canoe* relative to the *shore*.

PROBLEM TIP

When several different values of a quantity such as velocity occur in the same problem, use subscripts to identify each value of that quantity. In the diagram for this problem, you have three relative velocities. Assign subscripts that identify the object and the reference frame, as shown below.

$\vec{v}_{cs}$ = velocity of the **c**anoe relative to the **s**hore
$\vec{v}_{cw}$ = velocity of the **c**anoe relative to the **w**ater
$\vec{v}_{ws}$ = velocity of the **w**ater relative to the **s**hore

Identify the Goal

(a) The time, Δt_{SE}, it takes for the canoe to reach the far bank
(b) The displacement, $\Delta\vec{d}_S$, of the canoe from the campsite at the point where the canoe comes ashore
(c) The velocity, $\vec{v}_{cs}$, of the canoe relative to the shore

Variables and Constants

Known	Unknown
$\Delta\vec{d}_E = 624\text{ m}$	$\Delta\vec{d}_S$
$\vec{v}_{ws} = 2.0\,\frac{\text{m}}{\text{s}}[\text{S}]$	$\vec{v}_{ws}$
$\vec{v}_{cw} = 3.0\,\frac{\text{m}}{\text{s}}[\text{E}]$	$\vec{v}_{cw}$
	$\vec{v}_{cs}$

Strategy

The time it takes to cross the river depends *only* on the velocity of the canoe relative to the river and is independent of the motion of the river. Calculate the time it takes to paddle across the river from the expression that defines average velocity. Since time is a scalar, use absolute magnitudes for velocity and displacement.

Calculations

Substitute first

$$|\vec{v}_{cw}| = \frac{|\Delta\vec{d}_E|}{\Delta t_{SE}}$$

$$3.0\,\frac{\text{m}}{\text{s}} = \frac{624\text{ m}}{\Delta t_{SE}}$$

$$3.0\,\frac{\text{m}}{\text{s}}\Delta t_{SE} = \frac{624\text{ m}}{\cancel{\Delta t_{SE}}}\cancel{\Delta t_{SE}}$$

$$3.0\,\frac{\text{m}}{\text{s}}\Delta t_{SE} = 624\text{ m}$$

$$\frac{\cancel{3.0\,\frac{\text{m}}{\text{s}}}\Delta t_{SE}}{\cancel{3.0\,\frac{\text{m}}{\text{s}}}} = \frac{624\,\cancel{\text{m}}}{3.0\,\frac{\cancel{\text{m}}}{\text{s}}}$$

$$\Delta t_{SE} = 208\text{ s}$$

Solve for Δt first

$$|\vec{v}_{cw}| = \frac{|\Delta\vec{d}_E|}{\Delta t_{SE}}$$

$$|\vec{v}_{cw}|\Delta t_{SE} = \frac{|\Delta\vec{d}_E|}{\cancel{\Delta t_{SE}}}\cancel{\Delta t_{SE}}$$

$$\frac{\cancel{|\vec{v}_{cw}|}\Delta t_{SE}}{\cancel{|\vec{v}_{cw}|}} = \frac{|\Delta\vec{d}_E|}{|\vec{v}_{cw}|}$$

$$\Delta t_{SE} = \frac{|\Delta\vec{d}_E|}{|\vec{v}_{cw}|}$$

$$\Delta t_{SE} = \frac{624\,\cancel{\text{m}}}{3.0\frac{\cancel{\text{m}}}{\text{s}}}$$

$$\Delta t_{SE} = 208\text{ s}$$

(a) It took the canoeist 2.1×10^2 s (or 3.5 min) to paddle across the river when her canoe was pointed directly east across the river.

Strategy

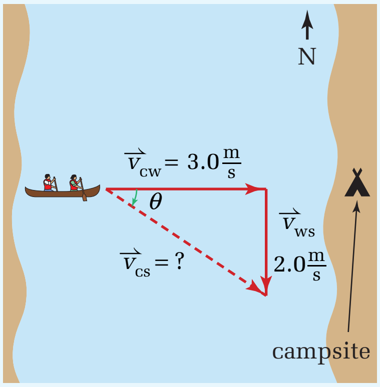
During the 208 s that the canoeist was paddling, the river current was carrying her south, down the river. To find the distance down river that she landed, simply find the distance that she would travel at the velocity of the current. Use the equation for the definition of average velocity. (**Note:** When using an answer to a previous part of a problem in another calculation, use the unrounded value.)

Calculations

$$\Delta\vec{d}_S = \vec{v}_{ws}\,\Delta t_{SE}$$

$$\Delta\vec{d}_S = 2.0\ \frac{\text{m}}{\cancel{\text{s}}}[\text{S}](208\ \cancel{\text{s}})$$

$$\Delta\vec{d}_S = 416\ \text{m[S]}$$



(b) The river carried the canoeist 4.2×10^2 m down river from the campsite.

To find the velocity of the canoe relative to the shore, find the vector sum of the velocity of the canoe relative to the water and the velocity of the water relative to the shore. Since the two vectors that you are adding are perpendicular to each other, the resultant is the hypotenuse of a right triangle. You can use the Pythagorean theorem to find the magnitude of the velocity.

$$|\vec{v}_{cs}|^2 = |\vec{v}_{cw}|^2 + |\vec{v}_{ws}|^2$$

$$|\vec{v}_{cs}|^2 = \left(3.0\ \frac{\text{m}}{\text{s}}\right)^2 + \left(2.0\ \frac{\text{m}}{\text{s}}\right)^2$$

$$|\vec{v}_{cs}|^2 = 9.0\left(\frac{\text{m}}{\text{s}}\right)^2 + 4.0\left(\frac{\text{m}}{\text{s}}\right)^2$$

$$|\vec{v}_{cs}|^2 = 13.0\left(\frac{\text{m}}{\text{s}}\right)^2$$

$$|\vec{v}_{cs}| = 3.6\ \frac{\text{m}}{\text{s}}$$

From the diagram, you can see that the tangent of the angle, θ, is the velocity of the water relative to the shore divided by the velocity of the canoe relative to the water. Use this expression to find θ.

$$\tan\theta = \frac{|\vec{v}_{ws}|}{|\vec{v}_{cw}|}$$

$$\tan\theta = \frac{2.0\ \cancel{\frac{\text{m}}{\text{s}}}}{3.0\ \cancel{\frac{\text{m}}{\text{s}}}}$$

$$\tan\theta = 0.6666$$

$$\theta = \tan^{-1} 0.6666$$

$$\theta = 33.69^\circ$$

(c) The velocity of the canoe relative to the shore was 3.6 m/s[E34°S].

Validate

In every case, the units cancelled to give the correct unit, (a) time in seconds, (b) displacement in metres and direction, and (c) velocity in metres per second and direction.

You would expect the velocity of the canoe relative to the shore to be larger than either the canoe relative to water and the water relative to the shore. You would also expect it to be less than the sum of the two magnitudes. All of these values were observed. The answers were all reasonable.

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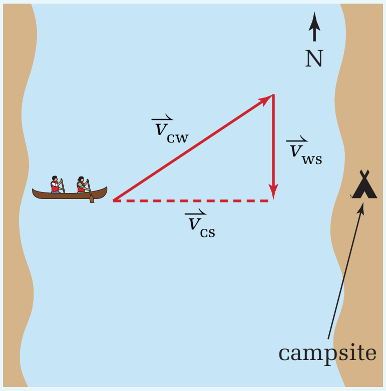
2. The canoeist in question 1 wants to head her canoe in such a direction that she will actually travel straight across the river to the campsite. (a) In what direction must she point the canoe? (b) Find the magnitude of her velocity relative to the shore. (c) How long will it take the canoeist to paddle to the campsite?

Frame the Problem

- Make a sketch of the problem.
- As the canoeist is paddling across the river, she must continuously *paddle upstream* to make up for the *current* carrying her *downstream*.
- Her *velocity relative* to the *shore* will have a *direction of east*, but the *magnitude* will be *less* than the *3.0 m/s* that she paddles *relative* to the *water*.
- The effective *distance* that she *paddles* will be *greater* than the *width* of the river, because she is, in a sense, going upstream.



Identify the Goal

(a) The direction, θ, in which the canoe must point
(b) The magnitude of the velocity, $|\vec{v}_{cs}|$, of the canoe relative to the shore
(c) The time interval, Δt, to paddle to the campsite

Variables and Constants

Known	Unknown
$\vec{v}_{ws} = 2.0\ \frac{\text{m}}{\text{s}}[\text{S}]$	$\lvert\vec{v}_{cs}\rvert$
$\lvert\vec{v}_{cw}\rvert = 3.0\ \frac{\text{m}}{\text{s}}$	θ
	Δt

Strategy

In this case, the magnitudes of the hypotenuse and opposite side of the triangle are known. Find the angle.

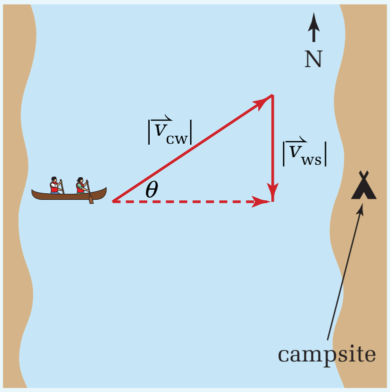
Calculations

$$\sin\theta = \frac{2.0\ \cancel{\frac{\text{m}}{\text{s}}}}{3.0\ \cancel{\frac{\text{m}}{\text{s}}}}$$

$$\sin\theta = 0.6667$$

$$\theta = \sin^{-1} 0.6667$$

$$\theta = 41.8^\circ$$



(a) The canoeist must point the canoe 42° upstream in order to paddle directly across the river to the campsite.

Strategy

Use the Pythagorean theorem to find the magnitude of the velocity of the canoe relative to the shore.

Calculations

Substitute first

$$|\vec{v}_{cw}|^2 = |\vec{v}_{cs}|^2 + |\vec{v}_{ws}|^2$$

$$\left(3.0\ \frac{m}{s}\right)^2 = |\vec{v}_{cs}|^2 + \left(2.0\ \frac{m}{s}\right)^2$$

$$9.0\left(\frac{m}{s}\right)^2 - 4.0\left(\frac{m}{s}\right)^2 = |\vec{v}_{cs}|^2 + 4.0\left(\frac{m}{s}\right)^2 - 4.0\left(\frac{m}{s}\right)^2$$

$$9.0\left(\frac{m}{s}\right)^2 - 4.0\left(\frac{m}{s}\right)^2 = |\vec{v}_{cs}|^2$$

$$5.0\left(\frac{m}{s}\right)^2 = |\vec{v}_{cs}|^2$$

$$|\vec{v}_{cs}| = 2.24\left(\frac{m}{s}\right)$$

Solve for $|\vec{v}_{cs}|$ first

$$|\vec{v}_{cw}|^2 = |\vec{v}_{cs}|^2 + |\vec{v}_{ws}|^2$$

$$|\vec{v}_{cw}|^2 - |\vec{v}_{ws}|^2 = |\vec{v}_{cs}|^2 + |\vec{v}_{ws}|^2 - |\vec{v}_{ws}|^2$$

$$|\vec{v}_{cs}|^2 = |\vec{v}_{cw}|^2 - |\vec{v}_{ws}|^2$$

$$|\vec{v}_{cs}| = \sqrt{|\vec{v}_{cw}|^2 - |\vec{v}_{ws}|^2}$$

$$|\vec{v}_{cs}| = \sqrt{\left(3.0\ \frac{m}{s}\right)^2 - \left(2.0\ \frac{m}{s}\right)^2}$$

$$|\vec{v}_{cs}| = \sqrt{9.0\left(\frac{m}{s}\right)^2 - 4.0\left(\frac{m}{s}\right)^2}$$

$$|\vec{v}_{cs}| = \sqrt{5.0\left(\frac{m}{s}\right)^2}$$

$$|\vec{v}_{cs}| = 2.24\ \frac{m}{s}$$

(b) The magnitude of the velocity of the canoe relative to the shore was 2.2 m/s.

Use the calculated velocity of the canoe relative to the shore and the known distance across the river to find the time interval for crossing the river.

Substitute first

$$\vec{v}_{cs} = \frac{\Delta\vec{d}}{\Delta t}$$

$$2.23\ \frac{m}{s}[E] = \frac{624\ m[E]}{\Delta t}$$

$$2.23\ \frac{m}{s}[E]\Delta t = \frac{624\ m[E]}{\cancel{\Delta t}}\cancel{\Delta t}$$

$$\frac{\cancel{2.23\ \frac{m}{s}[E]}\Delta t}{\cancel{2.23\ \frac{m}{s}[E]}} = \frac{624\ \cancel{m[E]}}{2.23\ \cancel{\frac{m}{s}}\cancel{[E]}}$$

$$\Delta t = 279\ s$$

Solve for Δt first

$$\vec{v}_{cs} = \frac{\Delta\vec{d}}{\Delta t}$$

$$\vec{v}_{cs}\Delta t = \frac{\Delta\vec{d}}{\cancel{\Delta t}}\cancel{\Delta t}$$

$$\frac{\cancel{\vec{v}_{cs}}\Delta t}{\cancel{\vec{v}_{cs}}} = \frac{\Delta\vec{d}}{\vec{v}_{cs}}$$

$$\Delta t = \frac{\Delta\vec{d}}{\vec{v}_{cs}}$$

$$\Delta t = \frac{624\ \cancel{m[E]}}{2.23\ \cancel{\frac{m}{s}}\cancel{[E]}}$$

$$\Delta t = 279\ s$$

(c) It took 2.8×10^2 s (or 4.7 min) for the canoe to cross the river and reach shore at the campsite.

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Validate

In every case, the units cancelled to give the correct units for the desired quantity.

You would expect that it would take longer to paddle across the river when taking the current into account than it would to paddle directly across relative to the water. It took about 70 s, or more than a minute, longer.

PRACTICE PROBLEMS

21. A kayaker paddles upstream in a river at 3.5 m/s relative to the water. Observers on shore note that he is moving at only 1.7 m/s upstream. Determine the velocity of the current in the river.

22. A jet-ski speeds across a river at 11 m/s relative to the water. The jet ski's heading is due south. The river is flowing west at a rate of 5.0 m/s. Determine the jet-ski's velocity relative to the shore.

23. A bush pilot wants to fly her plane to a lake that is 250.0 km [N30.0°E] from her starting point. The plane has an air speed of 210.0 km/h, and a wind is blowing from the west at 40.0 km/h.

(a) In what direction should she head the plane to fly directly to the lake?

(b) If she uses the heading determined in (a), what will be her velocity relative to the ground?

(c) How long will it take her to reach her destination?

24. An airplane travels due north for 1.0×10^2 km, then due west for 1.5×10^2 km, and then due south for 5.0×10^1 km.

(a) Use vectors to find the total displacement of the airplane.

(b) The time the airplane takes to fly the three different parts of the trip are as follows: 20.0 minutes, 40.0 minutes, and 12.0 minutes. Calculate the velocities for each of the three segments of the trip.

(c) Calculate the average velocity for the total trip. (Hint: this is not the same as the average speed.)

25. A swimmer is standing on the south shore of a river that is 120 m wide. He wants to swim straight across and knows that he can swim 1.9 m/s in still water. He drops a stick in the water and finds that it floats with the current to a point 24 m west in 30.0 s.

(a) Determine the direction in which the swimmer should head so that he lands directly across the river on the north bank.

(b) If he follows your advice, determine how long it will take him to reach the far shore.

26. A hiker heads [N40.0°W] and walks in a straight line for 4.0 km. She then heads [E10.0°N] and walks in a straight line for 3.0 km. Finally, she heads [S40.0°W] and walks in a straight line for 2.5 km.

(a) Determine the hiker's total displacement for the trip.

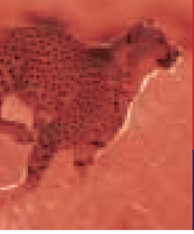
(b) In what direction would she have to head in order to walk straight back to her starting position?

(c) If her average walking speed was 4.0 km/h, how long did the total trip take?

27. A lone canoeist paddles from her cabin, heading directly east. When there is no wind, the velocity of the canoe is 1.5 m/s. However, a strong wind is blowing from the north, and the canoe is pushed southwards at a rate of 0.50 m/s.

(a) Use vectors to calculate the resultant velocity of the canoe relative to the shore.

(b) Check your solution by using the Pythagorean theorem.



INVESTIGATION 3-B

Go with the Flow

TARGET SKILLS

- Initiating and planning
- Predicting
- Performing and recording
- Communicating results

In this investigation, you will simulate the motion of a canoe travelling across a river. This process will help you to sharpen your skills of working with relative velocities and clarify your understanding of these concepts.

Prediction

Predict the point at which your "canoe" will come ashore on the "river bank" under several different conditions.

Problem

Test your predictions about the point where your canoe will come ashore on the river bank under several different conditions.

Determine the direction in which the canoe must head in order to reach the river bank directly across the river from where it started.

Equipment

- battery-powered toy car (or physics bulldozer)
- 2 retort stands
- stopwatch
- protractor
- metre stick
- newspaper
- masking tape
- string

Procedure

1. Make a paper river by taping together six sheets of newspaper. Newspaper sizes vary, but your river should end up being approximately 1 m wide and 3 m long. (A piece of brown wrapping paper can be used as an alternative to the newspaper.) Measure and record the exact width of your river.
2. A toy car will serve as the canoe. Design and carry out a procedure to determine
   (a) the canoe's speed
   (b) whether the canoe travels at a constant velocity

   Record your procedure, data, calculations, and conclusions.
3. Have one member of your group pull the river along at a constant velocity. Develop a technique for ensuring that the river "flows" at the same constant velocity throughout the investigation.
4. Design and carry out a procedure for determining the velocity of the river. Record your procedure, data, calculations, and conclusions.

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5. Predict how long it will take the canoe to cross the river from one edge to the other when the river is *not* flowing. Test your prediction.
6. Make the following predictions about the motion of the canoe when the river is flowing.
   - **(a)** Predict whether the motion of the river will affect the time it takes for the canoe to travel from one bank to the other. Explain your reasoning. Include in your explanation a sketch of what you think will happen, and the frames of reference that you considered.
   - **(b)** Assume that the canoe is pointed directly across the river. Predict where the canoe will come ashore on the opposite river bank.
   - **(c)** Predict the direction in which the canoe must be pointed for it to travel directly across the river. Draw a vector diagram to support your predictions.
   - **(d)** Predict the time it will take for the canoe to cross the river when pointed in the direction you determined in part (c).
7. Test your predictions according to the following procedures.
   - **(a)** Measure the time it takes for the canoe to cross the river when the river is not flowing.
   - **(b)** Based on your prediction in step 6(b), mark the starting point and the predicted ending point of the river-crossing when the river is flowing. Place a retort stand at each of the two positions and tie a string from one to the other along the predicted path. Start the river flowing. Start a stopwatch when you start the canoe, and time the crossing. Observe the crossing to see how well the canoe followed the predicted path.
   - **(c)** Develop a method to ensure that you can align the canoe in the direction predicted in step 6(c). Start the river flowing, then start the canoe crossing at the predetermined angle. Time the crossing with a stopwatch. Observe the motion of the canoe and the point where it goes ashore on the far side of the river.
8. If the direction that you predicted in step 6(c) and tested in step 7(c) did not result in the canoe going ashore directly across the river, re-evaluate your velocities and calculations. Refine and repeat your experiment several times until your observations match your predictions as closely as is reasonable.

Analyze and Conclude

1. What was your prediction about the effect of the motion of the river and the time it took for the canoe to cross the river when the canoe was pointed directly across the river? How well did your observations support your prediction? Explain.
2. Use the concept of frames of reference to answer the following question in two different (opposite) ways. Does the canoe move in the direction in which it is pointing?
3. How well did your observations support your predictions about the time interval of the crossing when the canoe was pointed in a direction that resulted in its moving directly across the flowing river? Explain.
4. How well were you able to predict the correct direction in which to point the canoe in order to cause it to move directly across the flowing river? If you had to make adjustments to your prediction and re-test the procedure, explain why this was necessary.
5. Discuss any problems you encountered in making and testing predictions involving relative velocities.

CAREERS IN PHYSICS

The "Breath of Life": The Art of Animation

Remember when you didn't have to get up in the morning and go to school? Given the chance now, you would probably like to sleep in late, but back then mornings meant getting up while it was still dark and planting yourself in front of the television with a bowl of cereal to watch old Looney Tunes or Pokémon. While most of us were first introduced to animation through morning cartoons, animation is anything but kids' stuff. It is a highly skilled art that draws fans of all ages, whether it's a classic Disney flick like *Snow White*, a Japanese Anime blockbuster movie like *Spirited Away*, or an Xbox video game.

The word "animation" comes from the Latin word *anima*, which means "breath of life." In the case of animation, giving a character or object life means putting it into motion. Still pictures are turned into moving pictures by flashing a series of gradually altered images, which can either be individual drawings called cells or individual photographs called frames, before the eye in rapid succession.

While the art of drawing forms the bedrock for all animation, the tools of the trade can range from pencils and paper, the tools of classical animation, to clay models, to 3D computer technology, used in films like *Ice Age* and *Shrek*. Another form of animation is stop-motion photography. It involves filming elaborate models on miniature sets one frame at a time, changing the positions of the models between the shots. Stop-motion gave life to the overgrown ape King Kong in 1933, and was used in the film *The Nightmare Before Christmas*.

What inspires budding animators? For Sean Ridgway, it was his early love of drawing and animation, fuelled by watching old Warner Brothers cartoons. Ridgway studied classical animation at Sheridan College in Oakville, Ontario, and now teaches drawing and animation at the Center for Arts and Technology in Fredericton, New Brunswick. He says that a strong sense of design and an understanding of the physics of motion and human mechanics are essential to creating realistic and convincing character movement.

No matter what technology is being used, according to Ridgway, "animation hasn't really changed all that much in the last seventy years." During the 1930s, the Walt Disney studios developed twelve principles of character animation that are still important today. One of these principles is called "anticipation," and can generally be defined as the preparation for an action. Ridgway says anticipation "is all about showing the audience what a character is about to do. It is always opposite to what the action is." For example, anticipation can be a reverse movement to accent a forward movement, like having a character crouch down before jumping into the air.

Ridgway has three words of advice for making a character's movement natural and believable: "Know your character." What do they eat? Where do they live? Are they old, young, happy, depressed? All of these factors affect the timing and posing of a character in a scene and whether or not that character is believable. "You are not just an animator," says Ridgway, "You are in a sense an actor and you want to know as much as possible about this character in order to convincingly and believably bring it to life."

Going Further

1. Lifelike movement is the goal of every animator. Ridgway recommends that aspiring animators study the natural world around them: "Study people, animals, anything! Look for different body types, walks, expressions, mannerisms, perspective, proportions, and be diligent in trying to incorporate these into your work." Try sketching your best friend, your teacher, or your pet.

3.3 Section Review

1. C Explain why the concept of relative velocity is useful to pilots and canoeists.

2. C Discuss whether all velocities can be considered relative velocities.

3. K/U When you are in a car moving at 50 km/h,
   (a) what is your velocity relative to the car?
   (b) what is your velocity relative to the ground?

4. K/U On a moving train, you walk to the dining car, which is forward of your own car. Draw velocity vectors of the train relative to the ground, you relative to the train, and you relative to the ground for a point on your trip towards and away from the dining car.

5. K/U State the object and reference frame of the resultant vector when the following velocity vectors are added.
   (a) plane relative to air + air relative ground
   (b) canoe relative to water + water relative ground
   (c) balloon relative to ground + ground relative to air
   (d) swimmer relative to ground + ground relative to water

6. C Use common language to communicate
   (a) velocity of air relative to the ground
   (b) the heading of someone in a kayak
   (c) velocity of water relative to the ground

7. K/U A canoe is headed directly across a river that is 200 m wide. Instead of moving with constant velocity, the canoe moves with a constant acceleration of 4.0×10^{-2} m/s^2. If the river is flowing with a constant velocity of 2.0 m/s, how long will it take for the canoe to reach the other side? How far down the river will it land? Sketch the shape of the path the canoe will follow.

8. I A boy heads north across a river at a speed of x m/s. A current of $\frac{x}{2}$ m/s heads west.
   (a) Develop a vector diagram to indicate where he will land on the opposite beach.
   (b) Develop a vector diagram to indicate the direction that he should head in order to land at the dock directly north of his starting position.

ELECTRONIC LEARNING PARTNER

Your Electronic Learning Partner has more information about motion in a plane.

UNIT PROJECT PREP

Simple visual effects can be impressive when they play with the viewer's expectations.

- How can other objects and changing backgrounds be used to create the illusion of motion?
- Can relative velocities be used to create comic or dramatic situations?
- Try using a strobe light to create interesting velocity effects.

  CAUTION Strobe lights can cause seizures in people with certain medical conditions.