



Student Content Brief – Introductory Level

## Vectors

### Background Information

Physics and Engineering deal with quantities that have both size and direction. These physical quantities have a special math language in which they are known as [vectors](#). In a science class you may have measured things like volume, mass, length, and area. These quantities all have a size, or magnitude, but do not have a direction. They are known as [scalar quantities](#).

If you have ever given directions you have probably used a type of vector language. “Go 5 blocks North and then turn right.” If you just told someone to “walk 5 blocks”, without specifying the direction, who knows where they would end up? In physics we use vectors to describe forces, displacement, velocity, and acceleration.

When two or more vectors are added together to get a total vector, this is called the [resultant vector](#). These are all terms that you will be exploring in navigating your Sea Perch.

### Introduction to Vectors and Forces

A [force](#) is defined as a push or a pull. The S.I. unit for forces are Newtons (N), although in your everyday life you probably use pounds (lb) for force units. The size of the force is important but so is the direction. Imagine a woman is pushing a grocery cart forward with 10 Newtons of force and the force of [friction](#) is working against her with a force of 10 N, as illustrated in the picture below.



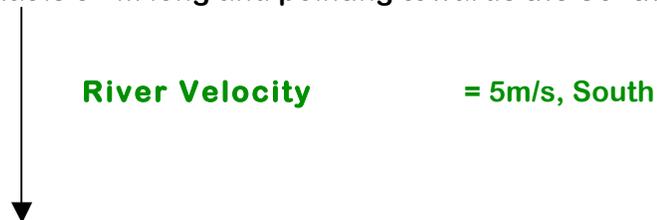
This could mean a few things. The total force acting on the cart is 0 N because your force is balanced by the force of friction. According to [Newton’s 2<sup>nd</sup> Law](#), if the sum of the forces is zero then the [acceleration](#) of the cart is also zero. An acceleration of zero either means the cart is not moving, or it is moving at a constant velocity.

If the woman pushed harder with a 15 N force and the force of friction stayed the same 10 N then the resultant would be 5 N in the direction of the woman’s push. It would be like a tug of war between the woman and friction, and she would win! This unbalanced force would cause the wagon to accelerate. What if she pushed the cart with 10 N of force through a sticky puddle on the floor? The stickiness would increase the force of friction to 15 N. In this scenario the friction would win the tug of war and the cart would [decelerate](#).

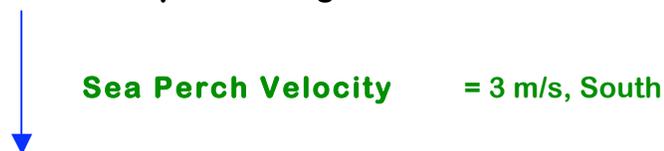
For your Sea Perch you will be adding the forces of your motor going forward and the drag of the water going backwards. If the force of the motor is greater than the drag of the water then your Sea Perch is accelerating. If the drag is greater than the force of your motor then your Sea Perch will start to slow down. If they are exactly equal to each other your Sea Perch is either at rest, or moving at a constant velocity.

### Using vectors to describe motion

Vectors are also used when describing an object's motion. If your Sea Perch were to be placed in a river that had a southwardly flowing current, then the motion of your Sea Perch would be a combination of the velocity of the river plus the velocity of your Sea Perch. If the water was flowing at 5 m/s, we could represent this with an arrow, a mathematical representation of a vector that is 5 cm long and pointing towards the South.



If your Sea Perch was able to move at a maximum speed of 3 m/s and you pointed it due South the vector representing the Sea Perch would like this.



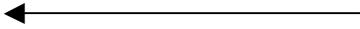
**What would the total velocity of the Sea Perch relative to the bank?**  
(Hint: Think about what happens when you are on a moving walkway at the airport.)



Think of all the different problems we could solve drawing different velocity vectors to find the total velocity of an object. Pilots do this all the time when navigating their airplanes. They have to take into account the velocity of their airplane (both size and direction) in conjunction with the velocity of the wind (both size and direction).

Think of a plane flying West at 10 m/s into a wind that is blowing East at 3 m/s. The following vector diagram could represent this problem.

Plane = 10 m/s, West



Wind = 3 m/s, East



When finding the resultant for vectors pointing in opposite directions think of adding directed numbers. When directed numbers have the same sign you add them together and keep the sign. When directed numbers have opposite signs you take the difference between the numbers and keep the sign of the larger number.

If the plane is flying in the negative direction and the wind is blowing in the positive direction we could write

$$-10 \text{ m/s} + 3 \text{ m/s} = -7 \text{ m/s}$$

The 7 m/s is the size of the resultant velocity vector of the plane and the negative sign shows the direction. This would mean the wind slows down the planes so it is actually moving at 7 m/s, West.

The picture of adding the vectors would look like this.



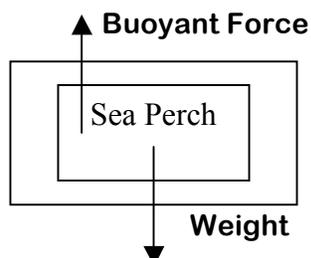
The read vector represents the resultant of 7 m/s in the Westerly direction.

Use the space below to write your own vector equation using an airplane as an example. Have a peer solve the equation using directed numbers and by drawing the vector picture. Remember your resultant must have both size and direction.

### **How Vectors Relate to your Sea Perch**

One of the first challenges you will face is making your Sea Perch neutrally buoyant. Imagine the forces acting on your Sea Perch in the water. Gravity, or the weight of the Sea Perch, will pull down on it. The size of this force will depend on the mass of your Sea Perch. The Buoyant Force will push up on your Sea Perch. This force will depend on how much water your Sea Perch displaces. (Think of when you sit in the tub, you displace a certain amount of water depending on the volume you take up in the tub.)

Physicists draw a free body diagram to show the forces acting on an object.



Think about what you have learned about adding vectors together to answer the following questions.

What has to happen to the force vectors if you want your Sea Perch to rise?

How can you accomplish this?

What has to happen to the force vectors if you want your Sea Perch to sink lower in the water?

How can you accomplish this?

One of the other challenges will be to make your Sea Perch move forward using the motors. Each motor produces a force vector that will act on your Sea Perch. To find the resultant motion of your Sea Perch in the horizontal direction you will add the vectors from each motor plus the vector of the water's drag on the Sea Perch.

Draw a free body diagram of the force vectors acting on your Sea Perch in the horizontal direction (forwards and backwards).

What will happen if the forward force of the motors is less than the drag of the water?

How can you use the idea of forces to explain how to move your Sea Perch backwards?

### **Additional Resources to Share with Students**

- If you would like to learn more about vectors, please visit the following URL: <http://www.physicsclassroom.com/class/vectors/u3l3a.cfm>
- For some additional information, try the following sites to engage in some interactive simulations <http://phet.colorado.edu/en/simulation/vector-addition> and <http://www.compadre.org/introphys/items/detail.cfm?ID=9403>