CHAPTER 20

Vectors And Scalars

CONTENTS

April 20, 2021

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1 INTRODUCTION TO VECTORS AND SCALARS

We come into contact with many physical quantities in the natural world on a daily basis. For example, things like time, mass, weight, force, and electric charge, are physical quantities with which we are all familiar. We know that time passes and physical objects have mass. Things have weight due to gravity. We exert forces when we open doors, walk along the street and kick balls. We experience electric charge directly through static shocks in winter and through using anything which runs on electricity.

There are many physical quantities in nature, and we can divide them up into two broad groups called **vectors** and **scalars**.

1.1 Scalars and vectors

Scalars are physical quantities which have only a number value or a size (magnitude). A scalar tells you **how much** of something there is.

DEFINITION

Scalar

A scalar is a physical quantity that has only a magnitude (size).

For example, a person buys a tub of margarine which is labelled with a mass of 500 g. The mass of the tub of margarine is a scalar quantity. It only needs one number to describe it, in this case, 500 g.

Vectors are different because they are physical quantities which have a size *and* a direction. A vector tells you **how much** of something there is *and* **which direction** it is in.

DEFINITION

Vector

A vector is a physical quantity that has both a *magnitude* and a *direction*.

For example, a car is travelling east along a freeway at 100 km · h^{-1} What we have here is a vector called the velocity. The car is moving at 100 km · h^{-1} (this is the magnitude) and we know where it is going – east (this is the direction). These two quantities, the speed *and* direction of the car, (a magnitude and a direction) together form a vector we call velocity.

Examples of scalar quantities:

- **mass** has only a value, no direction
- **electric charge** has only a value, no direction

Examples of vector quantities:

- **force** has a value and a direction. You push or pull something with some strength (magnitude) in a particular direction
- **weight** has a value and a direction. Your weight is proportional to your mass (magnitude) and is always in the direction towards the centre of the earth.

1.2 Vector notation

Vectors are different to scalars and must have their own notation. There are many ways of writing the symbol for a vector. In this book vectors will be shown by symbols with an arrow pointing to the right above it. For example, $\overrightarrow{F}$, $\overrightarrow{W}$ and $\overrightarrow{v}$ represent the *vectors* of force, weight and velocity, meaning they have both a magnitude *and* a direction.

Sometimes just the magnitude of a vector is needed. In this case, the arrow is omitted. For the case of the force vector:

- $\overrightarrow{F}$ represents the force vector
- F represents the magnitude of the force vector

2 GRAPHICAL REPRESENTATION OF VECTORS

Vectors are drawn as arrows. An arrow has both a magnitude (how long it is) and a direction (the direction in which it points). The starting point of a vector is known as the *tail* and the end point is known as the *head*.

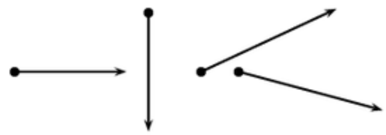


Figure 1: Examples of vectors

Figure 2: Parts of a vector

2.1 Directions

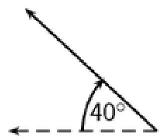
There are many acceptable methods of writing vectors. As long as the vector has a magnitude and a direction, it is most likely acceptable. These different methods come from the different methods of representing a direction for a vector.

Relative directions

The simplest way to show direction is with relative directions: to the left, to the right, forward, backward, up and down.

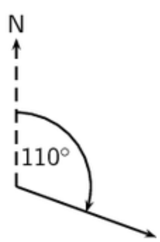
Compass directions

Another common method of expressing directions is to use the points of a compass: North, South, East, and West. If a vector does not point exactly in one of the compass directions, then we use an angle. For example, we can have a vector pointing $40°$ North of West. Start with the vector pointing along the West direction (look at the dashed arrow below), then rotate the vector towards the north until there is a $40°$ angle between the vector and the West direction (the solid arrow below). The direction of this vector can also be described as: W $40°$ N (West $40°$ North); or N $50°$ W (North $50°$ West).



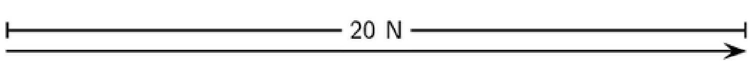
Bearing

A further method of expressing direction is to use a bearing. A bearing is a direction relative to a fixed point. Given just an angle, the convention is to define the angle clockwise with respect to North. So, a vector with a direction of $110°$ has been rotated clockwise $110°$ relative to North. A bearing is always written as a three digit number, for example $275°$ or $80°$ (for $80°$).



2.2 Drawing vectors

In order to draw a vector accurately we must represent its magnitude properly and include a reference direction in the diagram. A scale allows us to translate the length of the arrow into the vector's magnitude. For instance if one chooses a scale of 1 cm $= 2$ N (1 cm represents 2 N), a force of 20 N towards the East would be represented as an arrow 10 cm long pointing towards the right. The points of a compass are often used to show direction or alternatively an arrow pointing in the reference direction.



Method: Drawing Vectors

1. Decide upon a scale and write it down.
2. Decide on a reference direction
3. Determine the length of the arrow representing the vector, by using the scale
4. Draw the vector as an arrow. Make sure that you fill in the arrow head.
5. Fill in the magnitude of the vector.

WORKED EXAMPLE 1: DRAWING VECTORS 1

QUESTION

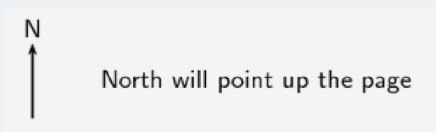
Draw the following vector quantity: $\vec{v}$ = 6 m · s^{-1} North

SOLUTION

Step 1: Decide on a scale and write it down.

1 cm = 2 m · s^{-1}

Step 2: Decide on a reference direction

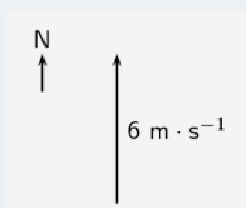


Step 3: Determine the length of the arrow at the specific scale.

If 1 cm = 2 m · s^{-1}, then 6 m · s^{-1} = 3 cm

Step 4: Draw the vector as an arrow

Scale used: 1 cm = 2 m · s^{-1}



WORKED EXAMPLE 2: DRAWING VECTORS 1

QUESTION

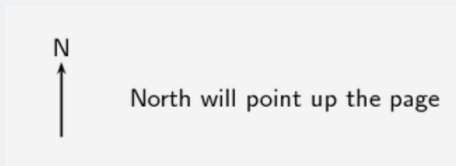
Draw the following vector quantity: $\vec{s} = 16$ m East

SOLUTION

Step 1: Decide on a scale and write it down.

1 cm = 4 m

Step 2: Decide on a reference direction



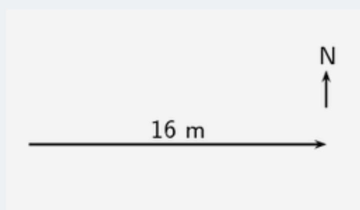
Step 3: Determine the length of the arrow at the specific scale.

If 1 cm = 4 m, then 16 m = 4 cm

Step 4: Draw the vector as an arrow

Scale used: 1 cm = 4 m

Direction = East



3 PROPERTIES OF VECTORS

Vectors are mathematical objects and we will now study some of their mathematical properties.

If two vectors have the same magnitude (size) *and* the same direction, then we call them equal to each other. For example, if we have two forces, $\overrightarrow{F}_1 = 20$ N *in the upward direction* $\overrightarrow{F}_2 = 20$ N *in the upward direction*, then we can say that $\overrightarrow{F}_1 = \overrightarrow{F}_2$.

DEFINITION

Equality of vectors

Two vectors are equal if they have the **same** magnitude and the **same** direction.

Just like scalars which can have positive or negative values, vectors can also be positive or negative. A negative vector is a vector which points in the direction *opposite* to the **reference positive direction**. For example, if in a particular situation, we define the upward direction as the reference positive direction, then a force $\overrightarrow{F}_1 = 30$ N *downwards* would be a *negative vector* and could also be written as $\overrightarrow{F}_1 = -30$ N. In this case, the negative sign (-) indicates that the direction of $\overrightarrow{F}_1$ is opposite to that of the reference positive direction.

DEFINITION

Negative vector

A negative vector is a vector that has the *opposite* direction to the reference positive direction.

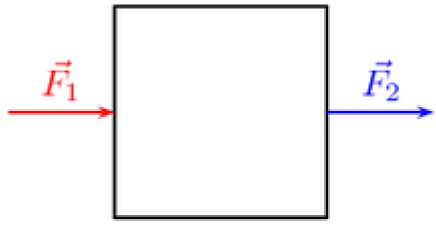
Like scalars, vectors can also be added and subtracted. We will investigate how to do this next.

3.1 Addition and subtraction of vectors

Adding vectors

When vectors are added, we need to take into account *both* their magnitudes *and* directions.

For example, imagine the following. You and a friend are trying to move a heavy box. You stand behind it and push forwards with a force $\overrightarrow{F}_1$ and your friend stands in front and pulls it towards them with a force $\overrightarrow{F}_2$. The two forces are in the *same* direction (i.e. forwards) and so the total force acting on the box is:



It is very easy to understand the concept of vector addition through an activity using the **displacement** vector.

Displacement is the vector which describes the change in an object's position. It is a vector that points from the initial position to the final position.

ACTIVITY

Adding vectors

Materials

Masking tape

Method

Tape a line of masking tape horizontally across the floor. This will be your starting point.

Task 1: Take 2 steps in the forward direction. Use a piece of masking tape to mark your end point and label it **A**. Then take another 3 steps in the forward direction. Use masking tape to mark your final position as **B**. Make sure you try to keep your steps all the same length!

Task 2: Go back to your starting line. Now take 3 steps forward. Use a piece of masking tape to mark your end point and label it **B**. Then take another 2 steps forward and use a new piece of masking tape to mark your final position as **A**.

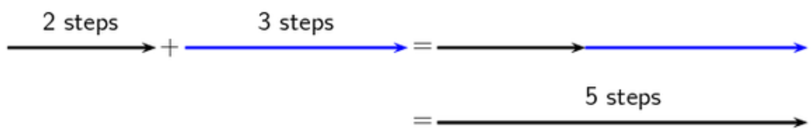
Discussion

What do you notice?

1. In *Task 1*, the first 2 steps forward represent a displacement vector and the second 3 steps forward also form a displacement vector. If we did not stop after the first 2 steps, we would have taken 5 steps in the forward direction in total. Therefore, if we add the displacement vectors for 2 steps and 3 steps, we should get a total of 5 steps in the forward direction.

2. It does not matter whether you take 3 steps forward and then 2 steps forward, or two steps followed by another 3 steps forward. Your final position is the same! The order of the addition does not matter!

We can represent vector addition graphically, based on the activity above. Draw the vector for the first two steps forward, followed by the vector with the next three steps forward.

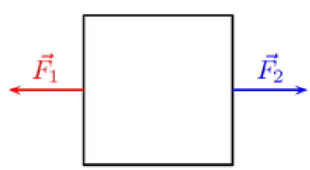


We add the second vector at the end of the first vector, since this is where we now are after the first vector has acted. The vector from the tail of the first vector (the starting point) to the head of the second vector (the end point) is then the sum of the vectors.

As you can convince yourself, the order in which you add vectors does not matter. In the example above, if you decided to first go 3 steps forward and then another 2 steps forward, the end result would still be 5 steps forward.

Subtracting vectors

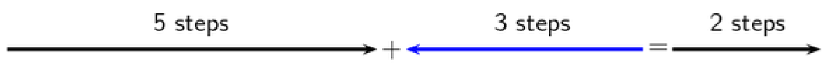
Let's go back to the problem of the heavy box that you and your friend are trying to move. If you didn't communicate properly first, you both might think that you should pull in your own directions! Imagine you stand behind the box and pull it towards you with a force $\overrightarrow{F}_1$ and your friend stands at the front of the box and pulls it towards them with a force $\overrightarrow{F}_2$. In this case the two forces are in *opposite* directions. If we define the direction your friend is pulling in as *positive* then the force you are exerting must be *negative* since it is in the opposite direction. We can write the total force exerted on the box as the sum of the individual forces:



What you have done here is actually to subtract two vectors! This is the same as adding two vectors which have opposite directions.

As we did before, we can illustrate vector subtraction nicely using displacement vectors. If you take 5 steps forward and then subtract 3 steps forward you are left with only two steps forward:

What did you physically do to subtract 3 steps? You originally took 5 steps forward but then you took 3 steps backward to land up back with only 2 steps forward. That backward displacement is represented by an arrow pointing to the left (backwards) with length 3. The net result of adding these two vectors is 2 steps forward:



Thus, subtracting a vector from another is the same as adding a vector in the opposite direction (i.e. subtracting 3 steps forwards is the same as adding 3 steps backwards).

TIP

Subtracting a vector from another is the same as adding a vector in the opposite direction.

The resultant vector

The final quantity you get when adding or subtracting vectors is called the resultant vector. In other words, the individual vectors can be replaced by the resultant – the overall effect is the same.

DEFINITION

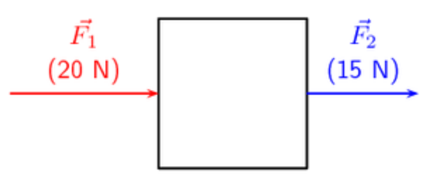
Resultant vector

The resultant vector is the single vector whose effect is the same as the individual vectors acting together.

We can illustrate the concept of the resultant vector by considering our two situations in using forces to move the heavy box. In the first case (on the left), you and your friend are applying forces in the same direction. The resultant force will be the sum of your two applied forces in that direction. In the second case (on the right), the forces are applied in opposite directions. The resultant vector will again be the sum of your two applied forces, however after choosing a positive direction, one force will be positive and the other will be negative and the sign of the resultant force will just depend on which direction you chose as positive. For clarity look at the diagrams below.

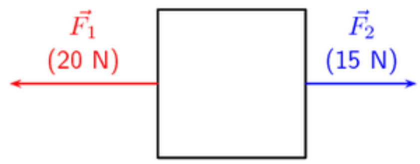
Forces are applied in the same direction

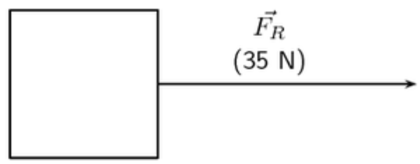
(positive direction to the right)

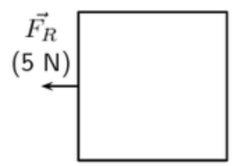


Forces are applied in opposite directions

(positive direction to the right)







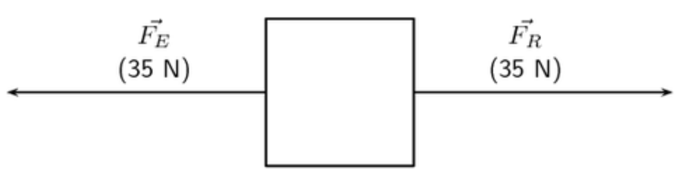
There is a special name for the vector which has the same magnitude as the resultant vector but the *opposite* direction: the **equilibrant**. If you add the resultant vector and the equilibrant vectors together, the answer is always zero because the equilibrant cancels the resultant out.

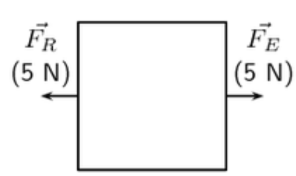
DEFINITION

Equilibrant

The equilibrant is the vector which has the *same magnitude* but *opposite direction* to the resultant vector.

If you refer to the pictures of the heavy box before, the equilibrant forces for the two situations would look like:





4 TECHNIQUES OF VECTOR ADDITION

Now that you have learned about the mathematical properties of vectors, we return to vector addition in more detail. There are a number of techniques of vector addition. These techniques fall into two main categories - graphical and algebraic techniques.

4.1 Graphical techniques

Graphical techniques involve drawing accurate scale diagrams to denote individual vectors and their resultants. We will look at just one graphical method: the head-to-tail method.

Method: Head-to-Tail Method of Vector Addition

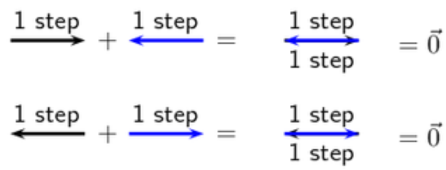
1. Draw a rough sketch of the situation.
2. Choose a scale and include a reference direction.
3. Choose any of the vectors and draw it as an arrow in the correct direction and of the correct length – remember to put an arrowhead on the end to denote its direction.
4. Take the next vector and draw it as an arrow starting from the arrowhead of the first vector in the correct direction and of the correct length.
5. Continue until you have drawn each vector – each time starting from the head of the previous vector. In this way, the vectors to be added are drawn one after the other head-to-tail.
6. The resultant is then the vector drawn from the tail of the first vector to the head of the last. Its magnitude can be determined from the length of its arrow using the scale. Its direction too can be determined from the scale diagram.

Let's consider some more examples of vector addition using displacements. The arrows tell you how far to move and in what direction. Arrows to the right correspond to steps forward, while arrows to the left correspond to steps backward. Look at all of the examples below and check them.

This example says 1 step forward and then another step forward is the same as an arrow twice as long – two steps forward.

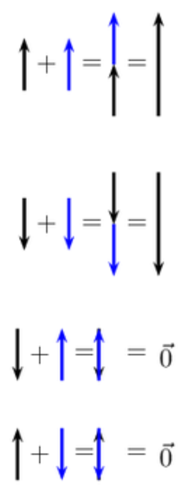
This example says 1 step backward and then another step backward is the same as an arrow twice as long – two steps backward.

It is sometimes possible that you end up back where you started. In this case the net result of what you have done is that you have gone nowhere (your start and end points are at the same place). In this case, your resultant displacement is a vector with length zero units. We use the symbol $\vec{0}$.

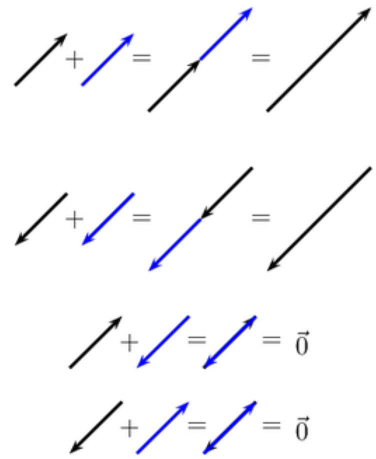


Check the following examples in the same way. Arrows up the page can be seen as steps left and arrows down the page as steps right.

Try a couple to convince yourself!



It is important to realise that the directions are not special - **forward** and **backward** or left and right are treated in the same way. The same is true of any set of parallel directions:



In the above examples the separate displacements were parallel to one another. However the same head-to-tail technique of vector addition can be applied to vectors in any direction.

WORKED EXAMPLE 3: HEAD TO TAIL ADDITION 1

QUESTION

A car breaks down in the road and you and your friend, who happen to be walking past, help the driver push-start it. You and your friend stand together at the rear of the car. If you push with a force of 50 N and your friend pushes with a force of 45 N, what is the resultant force on the car? Use the head-to-tail technique to calculate the answer graphically.

SOLUTION

Step 1: Draw a rough sketch of the situation

Step 2: Choose a scale and a reference direction

Let's choose the direction to the right as the positive direction. The scale can be 1 cm $= 10$ N.

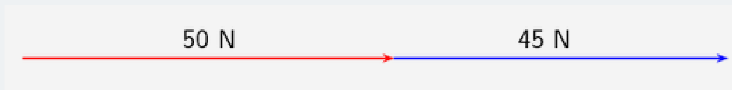
Step 3: Choose one of the vectors and draw it as an arrow of the correct length in the correct direction

Start with your force vector and draw an arrow pointing to the right which is 5 cm long (i.e. 50 N $= 5 \times 10$ N, therefore, you must multiply your cm scale by 5 as well).

WORKED EXAMPLE 3: HEAD TO TAIL ADDITION 1 (continued)

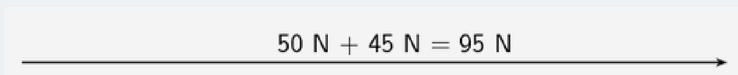
Step 4: Take the next vector and draw it starting at the arrowhead of the previous vector.

Since your friend is pushing in the same direction as you, your force vectors must point in the same direction. Using the scale, this arrow should be $4,5$ cm long.



Step 5: Draw the resultant, measure its length and find its direction

There are only two vectors in this problem, so the resultant vector must be drawn from the tail (i.e. starting point) of the first vector to the head of the second vector.



The resultant vector measures $9,5$ cm and points to the right. Therefore the resultant force must be 95 N in the positive direction (or to the right).

WORKED EXAMPLE 4: HEAD TO TAIL ADDITION 2

QUESTION

Use the graphical head-to-tail method to determine the resultant force on a rugby player if two players on his team are pushing him forwards with forces of $\vec{F}_1 = 60$ N and $\vec{F}_2 = 90$ N respectively and two players from the opposing team are pushing him backwards with forces of $\vec{F}_3 = 100$ N and $\vec{F}_4 = 65$ N respectively.

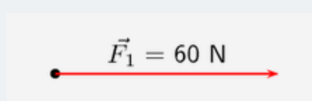
SOLUTION

Step 1: Choose a scale and a reference direction

Let's choose a scale of $0,5$ cm $= 10$ N and for our diagram we will define the positive direction as *to the right.*

Step 2: Choose one of the vectors and draw it as an arrow of the correct length in the correct direction

We will start with drawing the vector $\vec{F}_1 = 60$ N, pointing in the positive direction. Using our scale of $0,5$ cm $= 10$ N, the length of the arrow must be 3 cm pointing to the right.



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WORKED EXAMPLE 4: HEAD TO TAIL ADDITION 2 (continued)

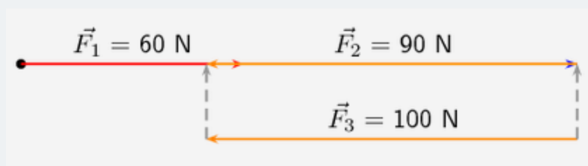
Step 3: Take the next vector and draw it starting at the arrowhead of the previous vector

The next vector is $\overrightarrow{F}_2 = 90$ N in the same direction as $\overrightarrow{F}_1$. Using the scale, the arrow should be $4,5$ cm long and pointing to the right.

Step 4: Take the next vector and draw it starting at the arrowhead of the previous vector

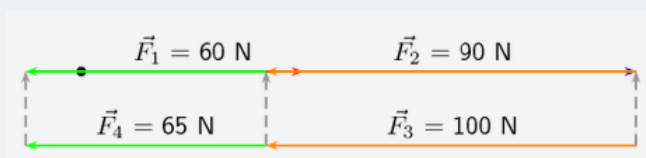
The next vector is $\overrightarrow{F}_3 = 100$ N in the *opposite* direction. Using the scale, this arrow should be 5 cm long and point to the *left*.

Note: We are working in one dimension so this arrow would be drawn on top of the first vectors to the left. This will get messy so we'll draw it next to the actual line as well to show you what it looks like.



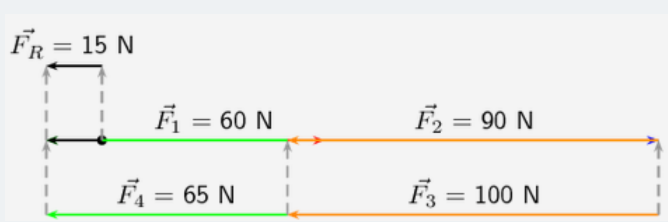
Step 5: Take the next vector and draw it starting at the arrowhead of the previous vector

The fourth vector is $\overrightarrow{F}_4 = 65$ N also in the opposite direction. Using the scale, this arrow must be $3,25$ cm long and point to the left.



Step 6: Draw the resultant, measure its length and find its direction

We have now drawn all the force vectors that are being applied to the player. The resultant vector is the arrow which starts at the tail of the first vector and ends at the head of the last drawn vector.



The resultant vector measures $0,75$ cm which, using our scale is equivalent to 15 N and points to the left (or the negative direction or the direction the opposing team members are pushing in).

4.2 Algebraic techniques

Vectors in a straight line

Whenever you are faced with adding vectors acting in a straight line (i.e. some directed left and some right, or some acting up and others down) you can use a very simple algebraic technique:

Method: Addition/Subtraction of Vectors in a Straight Line

1. Choose a positive direction. As an example, for situations involving displacements in the directions west and east, you might choose west as your positive direction. In that case, displacements east are negative.
2. Next simply add (or subtract) the magnitude of the vectors using the appropriate signs.
3. As a final step the direction of the resultant should be included in words (positive answers are in the positive direction, while negative resultants are in the negative direction).

Let us consider a few examples.

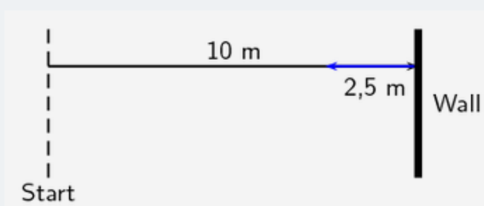
WORKED EXAMPLE 5: ADDING VECTORS ALGEBRAICALLY 1

QUESTION

A tennis ball is rolled towards a wall which is 10 m away from the ball. If after striking the wall the ball rolls a further $2,5$ m along the ground away from the wall, calculate algebraically the ball's resultant displacement.

SOLUTION

Step 1: Draw a rough sketch of the situation



Step 2: Decide which method to use to calculate the resultant

We know that the resultant displacement of the ball ($\vec{x_R}$) is equal to the sum of the ball's seperate displacements ($\vec{x_1}$ and $\vec{x_2}$):

$$\vec{x_R} = \vec{x_1} + \vec{x_2}$$

Since the motion of the ball is in a straight line (i.e. the ball moves towards and away from the wall), we can use the method of algebraic addition just explained.

WORKED EXAMPLE 5: ADDING VECTORS ALGEBRAICALLY 1 (continued)

Step 3: Choose a positive direction

Let's choose the **positive** direction to be towards the wall. This means that the **negative** direction is away from the wall.

Step 4: Now define our vectors algebraically

With right positive:

$$\vec{x_1} = +10,0 \text{ m}$$
$$\vec{x_2} = -2,5 \text{ m}$$

Step 5: Add the vectors

Next we simply add the two displacements to give the resultant:

$$\begin{aligned}\vec{x_R} &= (+10,0 \text{ m}) + (-2,5 \text{ m}) \\ &= +7,5 \text{ m}\end{aligned}$$

Step 6: Quote the resultant

Finally, in this case towards the wall is the positive direction, so: $\vec{x_R} = 7,5$ m towards the wall.

WORKED EXAMPLE 6: SUBTRACTING VECTORS ALGEBRAICALLY 1

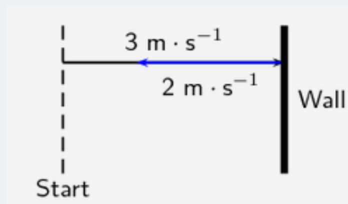
QUESTION

Suppose that a tennis ball is thrown horizontally towards a wall at an initial velocity of 3 m · s^{-1} to the right. After striking the wall, the ball returns to the thrower at 2 m · s^{-1}. etermine the change in velocity of the ball.

SOLUTION

Step 1: Draw a sketch

A quick sketch will help us understand the problem.



Step 2: Decide which method to use to calculate the resultant

Remember that velocity is a vector. The change in the velocity of the ball is equal to the difference between the ball's initial and final velocities:

$$\triangle\vec{v} = \vec{v_f} - \vec{v_i}$$

Since the ball moves along a straight line (i.e. left and right), we can use the algebraic technique of vector subtraction just discussed.

Step 3: Choose a positive direction

Choose the **positive** direction to be towards the wall. This means that the **negative** direction is away from the wall.

Step 4: Now define our vectors algebraically

$$\vec{v_i} = +3 \text{ m} \cdot \text{s}^{-1}$$
$$\vec{v_f} = -2 \text{ m} \cdot \text{s}^{-1}$$

Step 5: Subtract the vectors

Thus, the change in velocity of the ball is:

$$\begin{aligned}\triangle\vec{v} &= (-2 \text{ m} \cdot \text{s}^{-1}) - (+3 \text{ m} \cdot \text{s}^{-1}) \\ &= -5 \text{ m} \cdot \text{s}^{-1}\end{aligned}$$

Step 6: Quote the resultant

Remember that in this case towards the wall means a positive velocity, so away from the wall means a negative velocity: $\triangle\vec{v}$ = -5 m · s^{-1} away from the wall.

WORKED EXAMPLE 7: ADDING VECTORS ALGEBRAICALLY 2

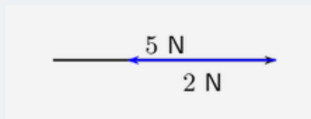
QUESTION

A man applies a force of 5 N on a crate. The crate pushes back on the man with a force of 2 N. Calculate algebraically the resultant force that the man applies to the crate.

SOLUTION

Step 1: Draw a sketch

A quick sketch will help us understand the problem.



Step 2: Decide which method to use to calculate the resultant

Remember that force is a vector. Since the crate moves along a straight line (i.e. left and right), we can use the algebraic technique of vector addition just discussed.

Step 3: Choose a positive direction

Choose the positive direction to be towards the crate (i.e. in the same direction that the man is pushing). This means that the negative direction is away from the crate (i.e. against the direction that the man is pushing).

Step 4: Now define our vectors algebraically

$$\begin{aligned}\overrightarrow{F_{man}} &= +5 \text{ N} \\ \overrightarrow{F_{crate}} &= -2 \text{ N}\end{aligned}$$

Step 5: Subtract the vectors

Thus, the resultant force is:

$$\begin{aligned}\overrightarrow{F_{man}} + \overrightarrow{F_{crate}} &= (5 \text{ N}) + (2 \text{ N}) \\ &= 7 \text{ N}\end{aligned}$$

Step 6: Quote the resultant

Remember that in this case towards the crate means a positive force: 7 N towards the crate.

Remember that the technique of addition and subtraction just discussed can only be applied to vectors acting along a straight line. When vectors are not in a straight line, i.e. at an angle to each other then simple geometric and trigonometric techniques can be used to find resultant vectors.

5 CHAPTER SUMMARY

- A scalar is a physical quantity with magnitude only.
- A vector is a physical quantity with magnitude and direction.
- Vectors may be represented as arrows where the length of the arrow indicates the magnitude and the arrowhead indicates the direction of the vector.
- The direction of a vector can be indicated by referring to another vector or a fixed point (e.g. $30°$ from the river bank); using a compass (e.g. N $30°$ W); or bearing (e.g. $53°$).
- The resultant vector is the single vector whose effect is the same as the individual vectors acting together.

6 EXERCISES

6.1 Exercise 1

Classify the following as either a vector, a scalar or neither:

1. Length.
2. Force
3. Direction
4. Height
5. Time
6. Speed
7. Temperature

6.2 Exercise 2

1. Classify the following quantities as scalars or vectors:

   1. 1 12 km

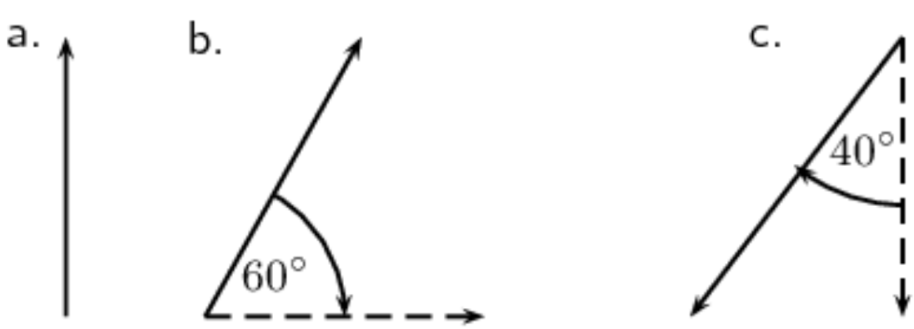
   1. 2 1 m south

   1. 3 2 m $\cdot$ s^{-1}, $45°$

   1. 4 $75°$, 2 cm

   1. 5 100 km $\cdot$ h^{-1}, $0°$

2. Use two different notations to write down the direction of the vector in each of the following diagrams:



6.3 Exercise 3

1. Draw each of the following vectors to scale. (Always include what scale you used)

    1.1 12 km South

    1.2 $1,5$ m N $45°$ W

    1.3 1 m · s^{-1}, $20°$East of North

    1.4 50 km · h^{-1}, $85°$

    1.5 5 mm, $225°$

6.4 Exercise 4

1. Harold walks to school by walking 600 m Northeast and then 500 m N $40°$ W. Determine his resultant displacement by using accurate scale drawings

2. A dove flies from her nest, looking for food for her chick. She flies at a velocity of 2 m · s^{-1} on a bearing of $135°$ and then at a velocity of $1,2$ m · s^{-1} on a bearing of $230°$. Calculate her resultant velocity by using accurate scale drawings.

3. A squash ball is dropped to the floor with an initial velocity of $2,5$ m · s^{-1}. It rebounds (comes back up) with a velocity of $0,5$ m · s^{-1}.

    3.1 What is the change in velocity of the squash ball?

    3.2 What is the resultant velocity of the squash ball?

4. A frog is trying to cross a river. It swims at 3 m· s^{-1} in a Northerly direction towards the opposite bank. The water is flowing in a Westerly direction at 5 m· s^{-1}. Find the frog's resultant velocity by using appropriate calculations. Use a sketch to help you.

5. Mpihlonhle walks to the shop by walking 500 m Northwest and then 400 m N $30°$ E. Determine her resultant displacement by doing appropriate calculations.

7 ANSWERS TO EXERCISES

7.1 Exercise 1

1. Scalar
2. Vector
3. Neither
4. Scalar
5. Scalar
6. Scalar
7. Scalar

7.2 Exercise 2

1. 1 Scalar

1. 2 Vector

1. 3 Vector

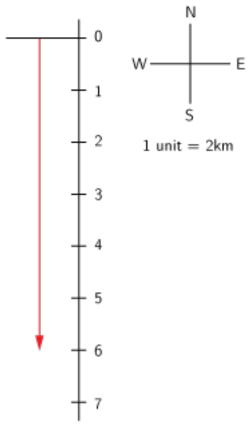
1. 4 Vector

1. 5 Vector

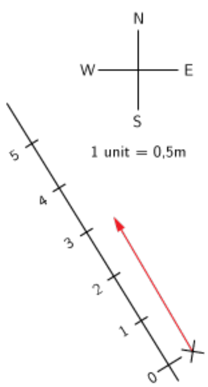
2. a) North, $0°$
   b) $E\ 60° N, N\ 30° E$
   c) $S\ 40° W, W\ 50° S$

7.3 Exercise 3

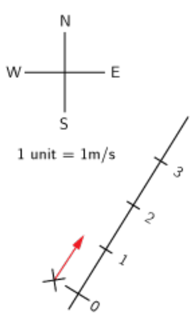
1.1



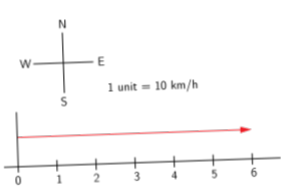
1.2

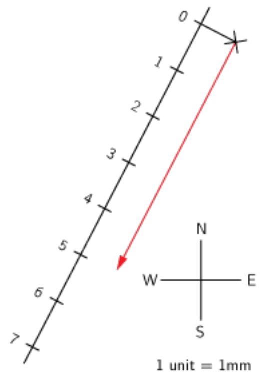


1.3



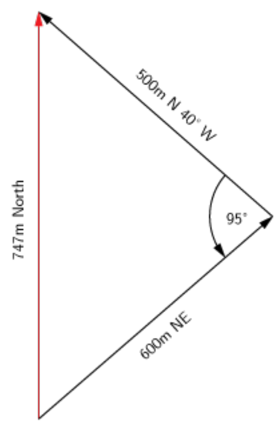
1.4



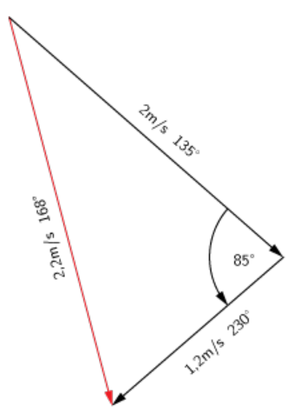


1.5

7.4 Exercise 4



1.



2.

3.1 $\Delta\vec{v} = 3$ m · s^{-1}, away from the floor

3.2 $v = 2$ m · s^{-1}, towards the floor

3. 6 m · s^{-1} at a bearing of $301°$ or N $59°$ W

4. 716.6 m on a bearing of $347.6°$