

## Vectors vs. Scalars in Physics

**Unit:** Mathematics

**NGSS Standards:** N/A

**MA Curriculum Frameworks (2006):** N/A

**AP Physics 1 Learning Objectives:** N/A

**Knowledge/Understanding Goals:**

- how vectors are used in an algebra-based physics course

**Language Objectives:**

- Accurately describe and apply the concepts described in this section, including the difference between “vector” and “scalar,” using appropriate academic language.

**Notes:**

In physics, most numbers represent quantities that can be measured or calculated from measurements. Most of the time, there is no concept of a “deficit” of a measured quantity. For example, quantities like mass, energy, and power can only be nonnegative, because in classical mechanics there is no such thing as “anti-mass,” “anti-energy,” or “anti-power.”

However, vector quantities have a direction as well as a magnitude, and direction can be positive or negative.

A rule of thumb that works *most* of the time in this class is:

**Scalar quantities.** These are almost always positive. (Note, however, that we will encounter some exceptions during the year. An example is electric charge, which can be positive or negative.)

**Vector quantities.** Vectors can be positive or negative. In any given problem, you will choose which direction is positive. Vectors in the positive direction will be expressed as positive numbers, and vectors in the opposite (negative) direction will be expressed as negative numbers.

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**Differences.** The difference or change in a variable is indicated by the Greek letter  $\Delta$  in front of the variable. Any difference can be positive or negative. However, note that a difference can be a vector, indicating a change relative to the positive direction (e.g.,  $\Delta x$ , which indicates a change in position), or scalar, indicating an increase or decrease (e.g.,  $\Delta V$ , which indicates a change in volume).

In some cases, you will need to split a vector in two vectors, one vector in the  $x$ -direction, and a separate vector in the  $y$ -direction. In these cases, you will need to choose which direction is positive and which direction is negative for both the  $x$ - and  $y$ -axes. Once you have done this, every vector quantity must be assigned a positive or negative value, according to the directions you have chosen.

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**Example:**

Suppose you have a problem that involves throwing a ball straight upwards with a velocity of  $15 \frac{\text{m}}{\text{s}}$ . Gravity is slowing the ball down with a downward acceleration of  $10 \frac{\text{m}}{\text{s}^2}$ . You want to know how far the ball has traveled in 0.5 s.

Displacement, velocity, and acceleration are all vectors. The motion is happening in the  $y$ -direction, so we need to choose whether “up” or “down” is the positive direction. Suppose we choose “up” to be the positive direction. This means:

- When the ball is first thrown, it is moving upwards. This means its velocity is in the positive direction, so we would represent the initial velocity as  $\vec{v}_0 = +15 \frac{\text{m}}{\text{s}}$ .
- Gravity is accelerating the ball downwards, which is the negative direction. We would therefore represent the acceleration as  $\vec{a} = -10 \frac{\text{m}}{\text{s}^2}$ .
- Time is a scalar quantity, so it can only be positive.

If we had to substitute the numbers into the formula:

$$\vec{d} = \vec{v}_0 t + \frac{1}{2} \vec{a} t^2$$

we would do so as follows:

$$\vec{d} = (+15)(0.5) + \left(\frac{1}{2}\right)(-10)(0.5)^2$$

and we would find out that  $\vec{d} = +6.25 \text{ m}$ .

The answer is positive. Earlier, we defined positive as “up”, so the answer tells us that the displacement is upwards from the starting point.

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What if, instead, we had chosen “down” to be the positive direction?

- When the ball is first thrown, it is moving upwards. This means its velocity is now in the negative direction, so we would represent the initial velocity as  $\vec{v}_o = -15 \frac{\text{m}}{\text{s}}$ .
- Gravity is accelerating the ball downwards, which is the positive direction. We would therefore represent the acceleration as  $\vec{a} = +10 \frac{\text{m}}{\text{s}^2}$ .
- Time is a scalar quantity, so it can only be positive.

If we had to substitute the numbers into the formula:

$$\vec{d} = \vec{v}_o t + \frac{1}{2} \vec{a} t^2$$

we would do so as follows:

$$\vec{d} = (-15)(0.5) + \left(\frac{1}{2}\right)(10)(0.5)^2$$

and we would find out that  $\vec{d} = -6.25 \text{ m}$ .

The answer is negative. Remember that “down” was positive, which means “up” is the negative direction. This means the displacement is upwards from the starting point, as before.

Remember: in any problem you solve, the choice of which direction is positive vs. negative is arbitrary. The only requirement is that every vector quantity in the problem needs to be consistent with your choice.

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