**Physical Education and Sport**

**Grade 13**

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What is the resultant force?

When an object is subject to several forces, **the resultant force is the force that *alone* produces the same acceleration as all those forces**.

For example, if 4 forces act on a block and cause it to accelerate 1 m/s2 south, then the resultant force is the force that, if applied *alone* to the block, will also make it accelerate 1 m/s2 south.

The reason why the resultant force is useful is that it allows us to think about several forces as though they were a single force. This means that to determine the effect that several forces have on an object, we only need to determine the effect that a single force has.

How to find the resultant force?

If we know the mass *m* of an object and the acceleration **a** produced by the forces that act on it, we can find the resultant force using **Newton's Second Law**. Indeed, according to Newton's Second Law, the force **F** that alone produces the acceleration **a** on an object of mass *m* is:

**F** = *m***a**

This force **F** is our resultant force. So, we can write:

**R** = *m***a**

Which indicates that the resultant force **R** has the same direction as **a**, and has magnitude equal to the product *ma*.

For example, if a box of 1.5 kg is subject to 5 forces which make it accelerate 2.0 m/s2 north-west, then the resultant force is directed north-west and has the magnitude equal to 1.5 kg × 2.0 m/s2 = 3.0 N.

Often, however, we know the forces that act on an object and we need to find the resultant force.

Experiments show that when an object is subject to several forces, **F**1, **F**2, ..., the resultant force **R** is the **vector sum** of those forces:

**R** = **F**1 + **F**2 + ...

Notice that this is not a mere sum of the magnitudes of the forces, but the **sum of the forces taken as vectors**, which is more involved because vectors have both a magnitude and a direction that we need to consider when doing the sum.

According to the above equation, if an object is subject to no forces, then the resultant force is **zero**, and if an object is subject to only one force, then the resultant force is **equal to that force**. These two cases are pretty simple, but what about an object subject to two or more forces? How do we perform the vector sum then?

To explain this clearly, we will now go through all the cases that can happen, from simple ones in which all the forces are parallel, to more complex ones in which the forces are not parallel, and show how to find the resultant force in each of them with the help of examples.

• Two forces acting in the same direction

Let's start with the simple case in which an object is subject to two forces that act in the same direction:

>N3 N4>

The resultant force is in the **same direction as the two forces**, and has the magnitude equal to the **sum of the two magnitudes**:

N7

• Two forces acting in opposite directions

Let's consider the case in which an object is subject to two forces that act in opposite directions.

If the two forces are *equal* in magnitude:

<N3 N3>

The resultant force will be **zero** because two opposite forces **cancel each other out**.

On the other hand, if the two forces are *not equal* in magnitude:

<N3 N5>

The resultant force will be in the **same direction as the force with the larger magnitude** (the 5 N force in the example), and have the magnitude equal to the **difference between the magnitudes of the two forces** (in the example that would be 2 N):

N2

• More than 2 forces parallel to one another

Let's now consider the case in which an object is subject to more than two parallel forces:

N3N4>

N5N6>

To find the resultant force in this case, we first sum all the forces that go in one direction, and then all the forces that go in the other direction:

(N3+N4)=N7

(N5+N6)=N11

At this point, we have two forces that are in opposite directions, which is a case that we already know how to solve: the resultant force has the same direction as the force with the larger magnitude (the 11 N force), and its magnitude is equal to the difference between the two magnitudes (4 N):

N4

• Two forces that is not parallel

In the previous cases, we have forces that are all parallel to one another. It's time to consider the case in which an object is subject to two forces that are not parallel.

For example, let's assume that we have a block subject to two forces, **F**1 and **F**2.

**F**1 has magnitude 50 N and is applied at a 45° angle, whereas **F**2 has magnitude 60 N and is applied horizontally, as shown in the free-body diagram below:

45°F2F1