Force

Newton's second law

The acceleration of a particle as measured from an inertial frame is given by the (vector) sum of all the forces acting on the particle divided by its mass.

$$a = F/m \text{ or } F = ma$$

Acceleration and force are measured at the same instant. If force becomes zero at an instant, acceleration also becomes zero at the same instant.

Working with Newton’s First and Second Law

Decide the System
We have to assume that forces are acting on a system and the system is at rest or in motion. In this context, the system may be a single particle, a block, a combination of two blocks one kept over the other or two blocks connected by a string etc. But there is a restriction for treating one as a system. All parts of the system should have identical acceleration.

Step 1 . Identify the Forces
Once the system is decided, make a list of the forces acting on the system due to all the objects other than the system. Any force applied by the system should not be included in the list of the forces (material from the chapter on forces should help you in deciding various forces exerted by the system and forces exerted by the objects on the system).

Step 2 . Make a Free Body Diagram
Represent the system by a point in a separate diagram and draw vectors representing the forces with this point as the common origin

Step 3 .Choose axes and Write Equations
Example
The example describes a block being pulled by a man with help of a string. The system under analysis is the block. It is accelerating in the horizontal direction. So there is net force in the horizontal direction. It is not accelerating in the vertical direction. Hence net force is vertical direction is zero.

First law of motion

If the (vector) sum of all the forces acting on a particle is zero then and only then the particle remains unaccelerated (i.e., remains at rest or moves with constant velocity).
We can say in vector notation

$$a = 0 \text{ if and only if resultant force } F = 0$$

A frame of reference in which Newton's first law is valid is called an inertial frame of reference.
A frame of reference in which Newton's first law is not valid is called a noninertial frame of reference. (Example: lamp in an elevator cabin whose cable had broken)

Example of lamp in an elevator whose cable had broken:
In the cabin when one measures with reference to the cabin, the lamp hanging from the ceiling has no acceleration. Hence the forces acting on the lamp, its weight (W) and the tension in the string supporting it are balancing each other. We can infer that W = T.
But for an observer on the ground, lamp is accelerating with acceleration g, when he considers the forces acting on the lamp as W and T once again, W is not equal to T as lamp is acceleating. Both cannot be right at the same time, and it means in one of the frames Newton's first law is not applicable.
Inertial frame: Hence inertial frame is a frame of reference in which Newton's first law is valid.
Is earth an inertial frame of reference?
Strictly it is not. But as a good approximation, earth can be taken as an inertial frame of reference.
All frames moving uniformly with respect to an inertial frame are themselves inertial.
This relation was derived from the relation that converts acceleration with respect to one frame into acceleration with respect to another frame. When the other frame is moving with uniform velocity it acceleration with respect to the frame in reference is zero.

Examples:
A train moving with uniform velocity with respect to ground, a plane flying with uniform velocity with respect to a high etc. The sum of forces acting on a suit case kept on the shelves of them with turnout to be zero.
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Second law of motion

The acceleration of a particle as measured from an inertial frame is given by the (vector) sum of all the forces acting on the particle divided by its mass.

$$a = F/m \text{ or } F = ma$$

Acceleration and force are measured at the same instant. If force becomes zero at an instant, acceleation also becomes zero at the same instant.