

Newton to Einstein

Section 0: Basic Definitions and Concepts

The Principle of Relativity. Galileo and Newton took this as fundamental. You cannot determine, from measurements carried out in a closed laboratory, if you are stationary or travelling at some speed or another. So any statement of **position** or of **velocity** always begs the question, position or velocity relative to what?

Frames of Reference. These are what positions and velocities (and accelerations) can be measured with respect to (relative to). A frame of reference may be thought of as points laid out from an **origin** with metre rules and with clocks, so that any point has coordinates (x, y, z) and any event has coordinates (x, y, z, t) . A **Cartesian** frame has rectilinear coordinates, but in general a frame of reference may be accelerating and rotating, and its geometry may be curvilinear.

Inertial and Non-Inertial Frames of Reference.

Cartesian and Non-Cartesian Frames of Reference.

Euclidean and Non-Euclidean Frames of Reference.

Most of our every-day frames of reference are non-inertial, non-Cartesian or non-Euclidean. So, e.g., a sailor has to handle spherical geometry to navigate, and a meteorologist needs to account for the Earth's rotation to make good weather forecasts.

Scalars and Vectors. Some physical quantities are simply **magnitudes** at a point (e.g. temperature). Some are magnitudes between two points (e.g. distance, voltage). These are **scalar** quantities. Some physical quantities have magnitude *and* direction at a point (e.g. wind speed, electric field) or between two points (e.g. displacement). These are **vector** quantities. A vector is something having both magnitude and direction.

Scalar and Vector Notation. A scalar will always be italic regular font (x, T). A vector may be embellished italic or simply bold Roman ($\underline{u}, \vec{u}, \bar{v}, \mathbf{x}$). The magnitude of the vector \bar{v} may be expressed as its *modulus*, $|\bar{v}|$, or simply by the same symbol as a scalar, $u \equiv |\mathbf{u}|$.

Vector Components. A vector is a physical thing, with a real magnitude and a real direction (e.g. an arrow drawn on the blackboard). Given a frame of reference, or coordinate system, the vector acquires **components**, which are the **projections** of the vector onto the axes of the coordinate system.

Vector Relationships. Vectors can be

- Added. Parallelogram rule, or add the components.
- Multiplied, by the dot product, yielding a scalar:

$$\vec{u} \cdot \vec{v} = uv \cos \theta$$

- Multiplied, by the cross product, yielding a vector normal to both:

Magnitude: $|\vec{u} \times \vec{v}| = uv \sin \theta$

Direction: $\vec{w} = \vec{u} \times \vec{v}$ is at right angles to both \vec{u} and \vec{v}

And $\vec{v} \times \vec{u} = -\vec{w}$

Right-Hand Rule: Rotate from \vec{u} to \vec{v} , then $\vec{u} \times \vec{v}$ points along the direction a screw would move in under that rotation.