Wroclaw University of Science and Technology

Physics

Author:

Tural Hajiyev – 270010

Supervised By:

Witold Jacak BEng, PhD

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Cylindrical and normal coordinate systems

A **coordinate system** is a method for identifying the location of a point on the earth. Most coordinate systems use two numbers, a **coordinate**, to identify the location of a point. Each of these numbers indicates the distance between the point and some fixed reference point, called the **origin**. The first number, known as the X value, indicates how far left or right the point is from the origin. The second number, known as the Y value, indicates how far above or below the point is from the origin. The origin has a coordinate of 0, 0.

Longitude and latitude are a special kind of coordinate system, called a **spherical coordinate system**, since they identify points on a sphere or globe. However, there are hundreds of other coordinate systems used in different places around the world to identify locations on the earth. All these coordinate systems place a grid of vertical and horizontal lines over a flat map of a portion of the earth.

A normal coordinate is a linear combination of Cartesian displacement coordinates. A linear combination is a sum of terms with constant weighting coefficients multiplying each term. The coefficients can be imaginary or any positive or negative number including +1 and -1. For example, the point or vector r = (1, 2, 3) in three-dimensional space can be written as a linear combination of unit vectors:

$$r = 1x + 2y + 3z$$

Speed is a quantity equal to the ratio of the distance traveled to time. If acceleration is equal to 0, the formula of speed in Cartesian coordinates is as follows:

$$v = s \div t$$

In equal acceleration ($a = const$), speed is equal to the division of speed difference to time:

$$a = \frac{v_x - v_{0x}}{t}$$

A cylindrical coordinate system is a three-dimensional coordinate system that specifies point positions by the distance from a chosen reference axis (axis L in the image opposite), the direction from the axis relative to a chosen reference direction (axis A), and the distance from a chosen reference plane perpendicular to the axis (plane containing the purple section). The latter distance is given as a positive or negative number depending on which side of the reference plane faces the point.

The position of any point in a cylindrical coordinate system is written as

$$r = r * \hat{r} + z * \hat{z}$$

Where $\hat{r} = (\cos\theta\,, \sin\theta, 0)$

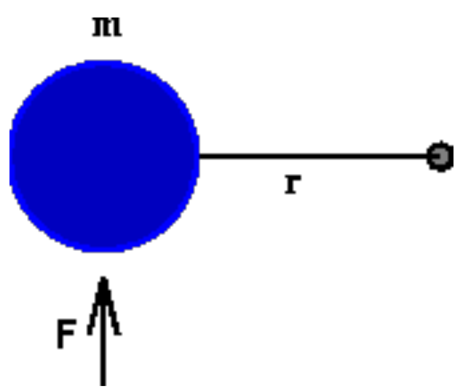
Speed of item in Cylindrical coordinate system:

$$v = (v_r\hat{r} + \ v_\theta\hat{\theta} + v_z\hat{z})$$

To find the acceleration, we need to differentatiate the speed calculation

$$a = \frac{\partial}{\partial t} v_r\hat{r} + \ v_\theta\hat{\theta} + v_z\hat{z}$$

Derivation of inertia forces; non-inertial systems



Suppose a particle of mass m is attached to a pivot by a thin rod of length r . As the particle travels around the circle, we know that the distance it travels is equal to the angle the rod sweeps out measured in radians multiplied by the radius r . Differentiating twice shows that

$$a = rA$$

where **A** is the angular acceleration (i.e. the rate at which the angular velocity of the rod is changing) and **a** is the instantaneous linear acceleration the particle experiences out on the circle.

By Newton's second law for linear motion, if we apply a force F to the particle, then F = m a . On the other hand, since we have a rotating system, we would like to work with torque , instead of force, so we multiply both sides of the equation by r . Then

$$T = Fr = mra$$

Finally, we use the equation derived about, to convert from linear acceleration to angular acceleration:

$$T = mra = mr(Ar)$$

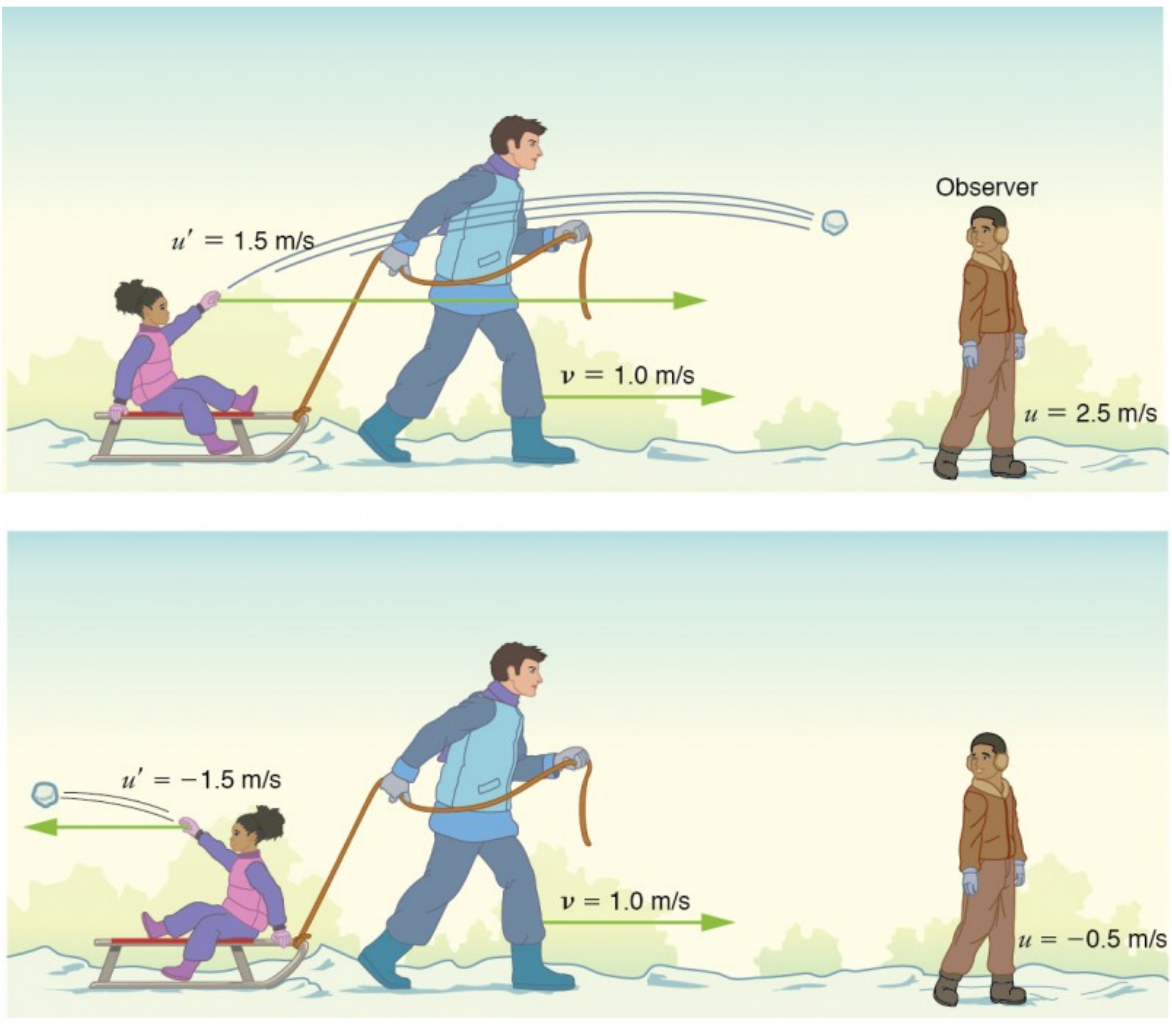
Rearranging terms gives the desired formula

$$T = mr^2A$$

Derivation of formulas for relativistic addition of velocity

Velocity is the directional speed of a object in motion as an indication of its rate of change in position as observed from a particular frame of reference and as measured by a particular standard of time (e.g. 60 km/h northbound).[1] Velocity is a fundamental concept in kinematics, the branch of classical mechanics that describes the motion of bodies.

Let v be the velocity of the sled relative to the Earth, u the velocity of the snowball relative to the Earth-bound observer, and u ′ the velocity of the snowball relative to the sled.



Classical Velocity Addition

$$u = v + \grave{u}$$

In relativistic physics, a velocity-addition formula is a three-dimensional equation that relates the velocities of objects in different reference frames. Such formulas apply to successive Lorentz transformations, so they also relate to different frames.

Either the light is an exception, or the classical velocity addition formula only works at low velocities. The latter is the case. The correct formula for one-dimensional relativistic velocity addition is

$$u = \frac{\boldsymbol{v} + \boldsymbol{\hat{u}}}{\boldsymbol{1} + \frac{\boldsymbol{v\hat{u}}}{\boldsymbol{c^2}}}$$

where v is the relative velocity between two observers, u is the velocity of an object relative to one observer, and $\boldsymbol{u'}$ is the velocity relative to the other observer. (For ease of visualization, we often choose to measure $\boldsymbol{u}$ in our reference frame, while someone moving at v relative to us measures $\boldsymbol{u'}$.) Note that the term $\frac{\boldsymbol{v\hat{u}}}{\boldsymbol{c^2}}$ becomes very small at low velocities, and $\boldsymbol{u} = \frac{\boldsymbol{v+\hat{u}}}{\boldsymbol{1+\frac{v\hat{u}}{c^2}}}$ gives a result very close to classical velocity addition. As before, we see that classical velocity addition is an excellent approximation to the correct relativistic formula for small velocities. No wonder that it seems correct in our experience.

The laws of dynamics, the equation of motion and its solutions for the simplest cases

Newton's laws are the laws of classical mechanics that allow us to write the equation of motion of a given mechanical system. In 1687, Isaac Newton's famous work, The Mathematical Beginnings of Natural Philosophy, was published. Here Newton describes three laws of mechanics. These laws are known as "Newton's axiom" or "Newton's laws".

The first law concerns the principle of inertia. It exists only in inertial systems and was first compiled by Galileo Galilei in 1638: If no force acts on the body, it either remains silent or maintains its speed.

Newton's first law is stated as follows: There are computational systems in which the body maintains a state of stillness at rest if it is not affected by other objects or balances the effects exerted on it, and a state of constant motion at right angles if it is at rest. Such computing systems are called inertial computing systems. That is, an object does not need an external force to move at a constant speed. If the substitution of the forces acting on the body is different from zero, it changes its speed, that is, it accelerates. In classical mechanics, this corresponds to the conditions of equilibrium.

Newton's second law - the differential law of motion - shows the relationship between the force applied to a material point and its acceleration. According to this law, in an inertial frame of reference, the acceleration received by a material point is directly proportional to the compensating force and inversely proportional to its mass. Newton's second law is expressed as follows:

$$\underset{a}{\rightarrow} = \frac{\overrightarrow{F}}{m}$$

If a body is affected by several forces, then Newton's second law is written as follows:

$$\sum_{i=1}^{n} \overrightarrow{F_i}$$

If the mass of an object changes with time, then Newton's second law can be expressed as follows: The change in the momentum of an object is equal to the force acting on it.

$$\frac{d(m\vec{v})}{dt} = \vec{F}$$

Newton's second law is only valid for speeds smaller than the speed of light and for inertial systems.

The third principle is based on interactions: The forces of interaction of two arbitrary bodies are modularly equal and opposite in direction. Forces are formed in pairs. However, they do not balance each other because they are applied to different objects. If body A acts on another body B with force, then body A will be affected by body B at the same value, but in the opposite direction. That is, the force creates the opposite force.

$$\boldsymbol{F}_{\boldsymbol{A}\to\boldsymbol{B}} = -\boldsymbol{F}_{\boldsymbol{B}\to\boldsymbol{A}}$$

Elements of general relativity, the principle of equivalence, the curvature of space

Physic starts with Newtonian mechanics and its Galilean invariance, that is a Principle of Relativity for the laws of mechanics with absolute time, which is compatible with Newton's law of gravity. The non-invariance of Maxwell's equations led us to replace the Galilean Principle of Relativity with an enlarged version, the Principle of Special Relativity, that covers electromagnetism and further requires invariance of the speed of light:

1. **Galilean Relativity:** "The laws of (Newtonian) mechanics are the same for all inertial observers (and time is absolute)."
2. **Special Relativity:** "The laws of physics are the same for all inertial observers and the speed of light in vacuum is invariant."

Generally, we can say that:

Principle of General Relativity: "The laws of physics are the same in all reference frames (for all observers)."

- General relativity is a generalization of special relativity for invariance under general coordinate transformations.
- Curved space is considered as intrinsically curved, defined by the metric, not by an embedding inflat space.
- In Einstein's theory, gravity is geometry matter that follows geodesics in curved space. Matter sources gravity.
- The Christoffel symbol is like the gauge field of gravity and the Riemann tensor is like its field strength.
- The Einstein-Hilbert action is the integral of the Ricci scalar.
- For weak fields, the Einstein-Hilbert action reduces to the Fierz-Pauli action and in the Dondergauge, the equation of motion is simply the Klein-Gordon.

- The Schwarzschild solution is the most general solution to the Einstein equations in the vacuum in the case of the static spherically symmetric matter distribution. If it is valid all the way to.

In the theory of general relativity, the equivalence principle is the equivalence of gravitational and inertial mass, and Albert Einstein's observation that the gravitational "force" as experienced locally while standing on a massive body (such as the Earth) is the same as the pseudo-force experienced by an observer in a non-inertial (accelerated) frame of reference.

Johannes Kepler, using Galileo's discoveries, showed knowledge of the equivalence principle by accurately describing what would occur if the Moon were stopped in its orbit and dropped towards Earth. This can be deduced without knowing if or in what manner gravity decreases with distance, but requires assuming the equivalency between gravity and inertia.

The equivalence principle was properly introduced by Albert Einstein in 1907, when he observed that the acceleration of bodies towards the center of the Earth at a rate of 1g (**g = 9.81 m/s2** being a standard reference of gravitational acceleration at the Earth's surface) is equivalent to the acceleration of an inertially moving body that would be observed on a rocket in free space being accelerated at a rate of 1g. Einstein stated it thus:

> ***we ... assume the complete physical equivalence of a gravitational field and a corresponding acceleration of the reference system.***

According to Albert Einstein's general theory of relativity, gravity is no longer a force that acts on massive bodies, as viewed by Isaac Newton's universal gravitation. Instead, general relativity links gravity to the geometry of spacetime itself, and particularly to its curvature.

In classical physics, time proceeds constantly and independently for all objects. In relativity, spacetime is a four-dimensional continuum combining the familiar three dimensions of space with the dimension of time.