Physics 1214 — Chapter 27: Relativity — 04/10

1 Invariance of Physical Laws

Fundamental Postulate of Special Relativity

All the laws of physics, including mechanics and electromagnetism, are the same in all inertial frames of reference.

Invariance of speed of light

The speed of light in vacuum is the same in all inertial frames of reference and is independent of the motion of the source.

Galilean coordinate transformation:

$$x = x' + ut, \quad y = y', \quad t = t'$$

2 Relative Nature of Simultaneity

Relative nature of simultaneity

Whether two events at different space points are simultaneous depends on the state of motion of the observer.

The time interval between two events depends on the frame of reference in which it is measured.

3 Relativity of Time

rest frame: the frame in which the object or person is not moving with respect to.

Time dilation

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - u^2/c^2}}$$

proper time: the time interval Δt_0 between two events that occur at the same point.
twin paradox: something or someone accelerated then decelerated–therefore one of the systems wasn't at rest in the inertial frame.

4 Relativity of Length

Length contraction parallel to motion:

$$l = l_0\sqrt{1 - \frac{u^2}{c^2}}.$$

proper length: a length measured in the rest frame of the body.
proper contraction: a length measured in any other frame but the rest frame.

Length contraction perpendicular to motion:

There is no length contraction perpendicular to the direction of relative motion.

5 The Lorentz Transformation

Lorentz transformation equations

$$x' = \frac{x - ut}{\sqrt{1 - u^2/c^2}}, \quad y' = y, \quad t' = \frac{t - ux/c^2}{\sqrt{1 - u^2/c^2}}$$

Space and time have become intertwined; we can no longer say that length and time have absolute meanings, independent of a frame of reference.

Relativistic velocity transformation

$$\nu' = \frac{\nu - u}{1 - u\nu/c^2}$$

6 Relativistic Momentum

Conservation of momentum: when two objects collide, the total momentum is constant.

Relativistic momentum

$$\vec{p} = \frac{m\vec{\nu}}{\sqrt{1 - \nu^2/c^2}}$$

$$\gamma = \frac{1}{\sqrt{1 - \nu^2/c^2}}$$

rest mass: m; the usual Newtonian mass; an object's mass at low velocity; compare with *relativistic mass.*

It is impossible to accelerate a particle from a state of rest to a speed equal to or greater than c.

$$F = \frac{ma}{(1 - \nu^2/c^2)^{\frac{3}{2}}} = \gamma^3 ma$$

relativistic mass

$$m_{rel} = \frac{m}{\sqrt{1 - \nu^2/c^2 = \gamma m}}$$

7 Relativistic Work and Energy

Relativistic kinetic energy

$$K = \frac{mc^2}{\sqrt{1 - \nu^2/c^2}} - mc^2$$

Total energy of an object

$$E = K + mc^2 = K + E_{rest} == \frac{mc^2}{\sqrt{1 - \nu^2/c^2}}$$

Rest energy of an object

$$E_{rest} = mc^2$$

Principle of conservation of mass and energy

In an isolated system, when the sum of the rest masses changes, there is always an equal and opposite change in the total energy other than the rest energy.

Relativistic energy-momentum relation

$$E^2 = \left(mc^2\right)^2 + (pc)^2$$

Energy and momentum of massless particles

$$E = pc$$

8 Relativity and Newtonian Mechanics