Special Relativity Overview

1 Topics

The guide provides an overview for special relativity and some helpful resources. For more materials, please see Science Knowledge or go to the url: https://scienceknowledge.webador.com/

1. Einstein's Postulates
    - Einstein's first postulate: The laws of physics have the same form in all inertial reference frames.
    - Einstein's second postulate: Light propagates through empty space with a definite speed independent of the speed of the observer (or source).
    - Understand that object cannot travel faster than the speed of light.
2. Time dilation
    - Deriving the equation for time dilation.
    - Calculating clocks' reading in different frames.
3. Length dilation
    - Deriving the equation for length contraction.
    - The longitudinal and transverse contraction of lengths.
    - The Paparazzi principle
4. Simultaneity
    - Lagging time by leading clocks
    - Understand that lagging time only occurs alone the direction of motion.
5. Paradoxes in special relativity
    - The moving clock paradox
    - The meter stick paradox
    - Rigid Bodies, a Pole Vaulter, and a Barn
6. Lorentz transformation
    - Lorentz transformation for an object's coordinate/position.
    - Lorentz transformation for time.
7. Velocity transformation
    - Identifying S and $S^{'}$ frames
    - Calculating velocity in different frames

8. Space time
    - Four vector components and representation of coordinates
    - Light cone
9. Relativistic momentum
    - Classical vs. relativistic momentum
    - Conservation of momentum
10. Relativistic energy
    - Total energy, Kinetic energy, and rest-mass energy.
    - Conservation of energy
    - Mass is not conserved
    - Energy of a photon($E = PC$)
    - Lorentz transformation invariant/scalar
        - The difference between "conserved" and "invariant."
11. Energy-momentum transformation
    - Energy and momentum in S and S' frames
    - Calculating energy and momentum using the CM(Center of momentum) frame.
    - Relativistic Doppler effect
        - Red shift and blue shift
        - Change in frequency/wavelength when an observer/source move toward/away.
        - Derive expressions for the relativistic Doppler shift.
    - Threshold energy for a nuclear reaction
12. Application of special relativity
    - Binding energy and mass defect
    - Decay into two particles
    - Decay into three particles

2 Recommended Sources

2.1 Textbooks

1. **Special Relativity by T. M. Helliwell (University Science Books, 2010)**
   - Thomas M. Helliwell is a physics professor at the Harvey Mudd college, received his B.A. from Pomona College and his Ph.D. at Caltech, where his speciality of research were on atomic physics and quantum mechanics. Each part of the book describing various key topic in special relativity and has various sample and practice questions.
   - **Purchase:** https://uscibooks.aip.org/books/special-relativity/
2. **Physics Volume 3, Openstax**
   - University Physics is a three-volume collection for two to three semesters calculus-based physics courses. Volume 1 covers mechanics, sound, oscillations, and waves. Volume 2 covers thermodynamics, electricity, and magnetism, and volume 3 covers optics and modern physics.
   - **Link:** https://openstax.org/books/university-physics-volume-3/pages/5-9-relativistic-energy

2.2 Lectures

1. **Introduction to Special Relativity, MIT**
   - **Lecture Link:** https://www.youtube.com/playlist?list=PLUl4u3cNGP61Zc3rR6wVM0kpsiyIq0fk8
   - **Full course:**https://ocw.mit.edu/courses/8-20-introduction-to-special-relativity-january-iap-2021/
   - **MIT OpenCourseWare:** https://ocw.mit.edu/
2. **Lectures by Professor Leonard Susskind, 2019**
   - **Lecture link:** https://www.youtube.com/playlist?list=PLD9DDFBDC338226CA
3. **Fundamentals of Physics with Ramamurti Shankar, YaleCourses 2014**
   - **Link:** https://www.youtube.com/playlist?list=PLFE3074A4CB751B2B
   - **Yale Open Course:** https://oyc.yale.edu/
4. **Special Relativity by Khan Academy**
   - **Link:** https://www.khanacademy.org/science/physics/special-relativity
   - **Khan Academy:** https://www.khanacademy.org/

3 Tips

- **Draw as many diagrams of the situation** described in the problem statement as are needed to make the problem and your analysis clear. For most problems, a diagram is expected even if the problem statement does not ask for one.
- **Express your answers algebraically** first, and substitute number at the end. The approach is more general this ways and allows your answers to be more organized, clear, and are likely to reduce errors by avoiding calculation mistakes or by identifying mistakes by checking units.
- **Practice problems and summarizing your mistakes.** Learning special relativity can be confusing, especially at the beginning. It is important to get practice to examine your skills and understanding.