

FYS3120 Classical Mechanics and
Electrodynamics

Bonus discussion before midterm

March 12, 2026

Remember the formula sheet on the exam!

Problem 1 A very, very fast train.

A train moves with speed $v = 0.8c$. The train has length $L_0 = 100$ m at rest. The train approaches a straight tunnel with length $d_0 = 60$ m. Let us call the rest frame of the tunnel S , and the frame comoving with the train (i.e. the rest frame of the train) is called S' .

- Draw the Minkowski diagram where the tunnel is at rest. Draw the worldlines of the front and back end of the train in this Minkowski diagram.
- Calculate the length of the train in the rest frame of the tunnel, S .
- Draw the Minkowski diagram for the situation in S' .
- Calculate the length of the tunnel in the rest frame of the train, S' .
- Is the train ever completely (with both ends) inside the tunnel? Explain your answer.

Problem 2

- What are the conserved quantities in a relativistic collision?
- Show that $E^2 = p^2c^2 + m^2c^4$ using $E = \gamma mc^2$ and $p = \gamma mv$.

Problem 3 Relativistic collision between two particles.

Consider a relativistic elastic collision between two particles, forming two output particles. Particle i has four-momentum P_i^μ , where $i \in \{1, 2\}$ label the input particles and $i \in \{3, 4\}$ the output particles. Each particle has (rest) mass m_i , momentum $\mathbf{p}_i$, and energy E_i . The momentum of particle 1 and 2 are considered to be along the same direction, whereas the momentum of particle 3 is at an angle θ compared to this direction, and particle 4 is at an angle ϕ .

- Draw the setup for this problem.
- Using the conservation laws from the previous exercise, what is the difference in four-momentum between particle 3 and 1 equal to?
- Calculate the invariant scalar product on both sides of the equation obtained in b) in terms of the energy and the momentum of the particles.
- Now we consider ourselves to be in the rest frame of particle 2. What can we now immediately eliminate from the equation we had in b)?

- e) Use energy conservation to eliminate E_4 from the equation.
- f) We now seek to apply this result to a particular system. Consider the input particles to be a photon and an electron at rest, and the output particles to be a photon and an electron with some unknown momentum $\mathbf{p}$. What is the rest energy and the momentum of the photon in terms of its energy?
- g) Label the particles and insert into the equation from e). What is the angle between the directions of the incoming and outgoing photons in terms of their energies?