PRACTICE TEST: OPTICS & RELATIVITY   NAME: ....

TIME: 15 minutes for part A, 45 minutes in total

PART A: SHORT QUESTIONS

REMARKS:
- No aids (calculator, „Formeln und Tafeln", formula sheet) allowed
- Always express numerical results as rounded decimal numbers (except in ratios)
- Derivation required for numerical results

1. On the reverse side explain the term *focal length* for a convex lens.

2. Tick the correct statements:
   - ☐ Proper time is independent of the reference frame.
   - ☐ The propagation speed of light is lower in water than in air.
   - ☐ A 100 keV electron is faster than a 100 MeV proton.
   - ☐ There is no internal reflexion for a light ray going from air into glass.

3. Calculate the Lorentz factor for a particle moving at one third of the speed of light.

4. A light ray travels through three layers of different liquids. List the refractive indices (n_1, n_2, n_3) in increasing order. Give reasons for your solution.
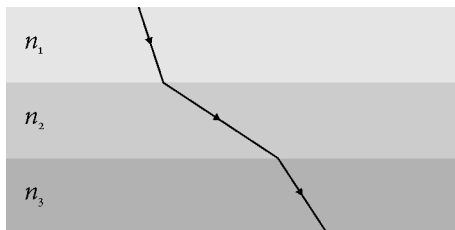
5. *Muons* have a mass of about 210 MeV/c². Calculate the total energy and the kinetic energy of a muon with a momentum of 280 MeV/c.

**SOLUTIONS:** 2. ☑ ☑ ☑ ☑; 3. 1.06; 4. $n_2 < n_3 < n_1$; 5. 350 MeV, 140 MeV

Remarks:

- ‣ Write your solutions to the problems on the answer sheet. Start a new page for every problem.
- ‣ An algebraic solution and all values used in calculations are required to get the full mark.
- ‣ Results must be rounded to a reasonable number of significant figures.

1. The *Tevatron* at the *Fermi National Accelerator Laboratory* is a synchrotron accelerator which accelerates protons (rest energy 938 MeV) and antiprotons in a 6.28 km long ring to kinetic energies of up to 1 TeV.

   a) Calculate the Lorentz factor for the protons at maximum energy. How close is their speed to the speed of light (in meters per second)?

   b) In 2007 physicists at the Fermilab discovered a short-lived particle called *Xi*. In its rest frame it has a mean life-time of only 0.29 ns. One of the observed Xi particles had a speed very close to the speed of light and left a trace some 64 cm long.

      What is the Lorentz factor describing the Xi particle in the lab frame?

2. The radioactive isotope Na-22 decays into the stable isotope Ne-22 with a half life of 2.6 years.

   a) Calculate the energy emitted in this decay. Compare your result to the value found in the corresponding energy level diagram ("Formeln und Tafeln", p. 185). In what form is the "lost" energy emitted?

   b) Calculate the binding energy of Ne-22 and compare it to the value you can read from the corresponding diagram in "Formeln, Tabellen, Begriffe".

3. Two parallel light rays (1 and 2) hit a Plexiglas prism with isosceles base (see figure).
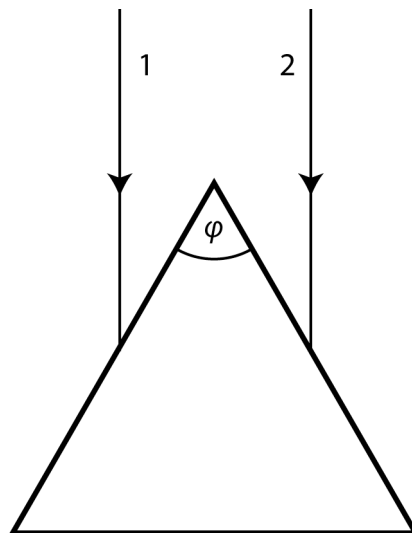
   a) Prove that the angle between the rays reflected on the prism equals $2 \cdot \varphi$. Does this result depend on the value of φ or the direction of the incoming (parallel) light rays?

   b) Calculate the angle of refraction for ray 1. Draw the path of that light ray through the prism until it gets back into the air.

   c) Sketch a light ray entering the prism which experiences total internal reflexion.

Solutions: 1. 1'070, 130 m/s, 7.4; 2. 2.85 MeV (2.843 MeV), – 172.7 MeV (7.8 MeV per nucleon); 3. 36 °