

exercises for mechanics I      **sheet 12**

[ tutorials 23.5. and 30.5., hand-in 3.6., solutions please in English ]

**Exercise 1:** The spectral line of an atomic transition has the wavelength 589 nm at rest. At which wavelength do we observe the transition, if

- (a) the source is moving away from us at half the speed of light? (2 points)
- (b) the source is moving towards us at the same speed? (2 points)

A red light has the wavelength  $\lambda = 700$  nm, a green one  $\lambda' = 475$  nm.

- (c) How fast should a car be driven, in order to observe a red light as green? (2 points)

**Exercise 2:** A particle moves in a constant force field:  $\vec{F} = mg \vec{e}_x$ ,  $g = 9.8$  m/s<sup>2</sup>.

- (a) Determine  $x(t)$  with the initial conditions  $x(0) = \dot{x}(0) = 0$ . (3 points)
- (b) When has the velocity reached 99% of the speed of light? (3 points)

**Exercise 3:** Cosmic radiation consists amongst others of protons, which can be very energetic. If a cosmic proton with the energy  $E = 10^3$  TeV collides on an atmospheric proton, how large is the collision energy in the center of mass frame of both protons? (The velocity of the atmospheric proton as well as its binding energy within a nucleus can be ignored.) [For comparison: the center of mass energies at the LHC are about 14 TeV.] (6 points)

**Exercise 4:** Consider a light source, moving with velocity  $v$  along the  $x$  axis. In its rest frame  $\Sigma'$ , the source emits a beam of frequency  $\nu'$  at angle  $\theta'$  with respect to the  $x$  axis. The 4-momentum of the source in  $\Sigma'$  thus reads

$$P' = (E'/c, \vec{p}') = \frac{h\nu'}{c} (1, \cos \theta', \sin \theta', 0) .$$

- (a) Determine the 4-momentum in the rest system  $\Sigma$ . (2 points)
- (b) Which frequency is measured in  $\Sigma$ ? (2 points)
- (c) What is the angle  $\theta$  of the beam with respect to the  $x$  axis in  $\Sigma$ ? (2 points)

Die Prüfung zur Mechanik I findet am Montag den 13.06. um 13:15-15:45 Uhr im Hörsaal A6 statt. Um rechtzeitig anfangen zu können ist es empfehlenswert, schon 10-15 Minuten vor dem Start dabei zu sein. Keine Hilfsmittel sind erlaubt.