# Electromagnetic Waves

## Basic Problems

1. Calculate the wavelength of the radio station DRS 3, which transmits on 88.75 MHz.
2. The antennas used in mobile phones usually have a length of a quarter of a wavelength. How long are the antennas for the 3G frequency band (1'900 MHz)?
3. What would be the magnitude of the electric field vector in an electromagnetic wave whose magnetic field has the same magnitude as the horizontal component of the terrestrial magnetic field in Zurich?
4. What is the wavelength of red light (650 nm) in acrylic glass (Plexiglas M222)?
5. A laser beam with a power of 3.5 mW has a diameter of 1.3 mm. Calculate the magnitudes of the electric and the magnetic field vector.
6. Microwaves are diffracted at a double slit with slit separation 8.5 cm. The first bright fringe is measured at an angle of 25° to the incoming waves. Calculate the frequency of the microwaves.
7. The light of a He-Ne laser (632.8 nm) hits a grating with 500 lines/cm. The resulting pattern is observed on a screen 4.5 m from the grating. Calculate the positions of the first three principal maxima.
8. The spectrum of a sodium lamp ("Formeln, Tabellen und Begriffe" p 194) is analysed with a spectrometer using a grating (5000 lines/mm). Calculate the distance between the two yellow lines on a screen 4.5 m away.
9. Explain why X-rays with a wavelength of some picometres can be used to investigate the structure of crystalline structures, e.g. metals or salt crystals.
10. In a first experiment, white light hits a diffraction grating. In a second experiment, it passes a glass prism. Sketch the spectrum in the first principal maximum and after the prism, respectively.
11. In order to measure the thickness of a sheet of paper you determine the diffraction pattern of green laser light (532 nm) hitting a paper strip on one of its edges. The first minima on a screen 2.5 m away are at 1.1 cm from the zeroth maximum. Calculate the thickness of the paper.
12. In his painting „Un dimanche après-midi à la Grande Jatte", pointillist painter Georges Seurat used coloured dots 2 mm apart. How far from the painting do the points start to dissolve into continuous areas? You may assume a diameter of 4 mm for the pupil of a human eye. Why and how does this minimum distance depend on the illumination in the room?

## Supplementary Problems

13. Identify electromagnetic waves you use in your everyday life. Find out about their basic parameters (wavelength, intensity).
14. Home experiment: Use a laser pointer to measure the thickness of a hair. Describe your setup, write down the measured values and your calculation.
15. On a clear day you happen to have the opportunity to float in a hot air balloon at a height of 3.5 km. What is the minimum distance between two red cars in order for you to be able to clearly distinguish them?
16. The following problems shall demonstrate that our eyes are optimised for the physical limits of resolving power.
    a) The pupil of the human eye has a typical diameter of 3 mm (in normal daylight). Calculate the angular resolution for visible light (e.g. $\lambda$ = 600 nm).
    b) The photoreceptors in the retina have a mutual distance of 1.5 µm. They are some 20 mm behind the pupil. Calculate their angular resolution and compare the result to the one in a).

Numerical Solutions: 1. 3.3 m; 2. 3.9 cm; 3. 6.4 kV/m; 4. 440 nm; 5. 1.0 kV/m, 3.3 µT; 6. 8.4 GHz; 7. 14 cm/28 cm/42 cm; 8. 1.3 cm; 11. 120 µm; 12. 14 m; 15. about 1 m; 16. 0.24 mrad, 0.15 mrad