Computer Simulation in Science

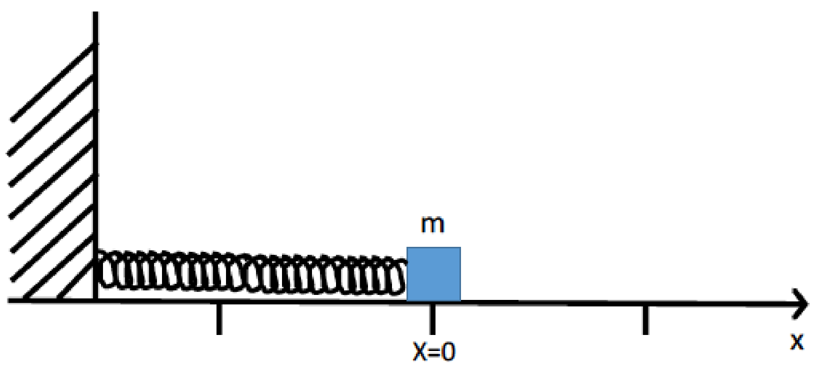
Specialisation
Detector Physics

BERGISCHE UNIVERSITÄT WUPPERTAL

Problems for the self-assessment of applicants

The applicants are expected to have acquired the expertise in their Bachelor studies in order to solve the problems given below. This is seen as a pre-requisite to succeed in the specialisation *Detector Physics* of the CSIS Master programme.

1. **Harmonic oscillation of a mass fixed to a spring**
   A body with mass m is fixed to a wall with a spring with spring constant k. Initially, the body is at the equilibirium position $x = 0$ where there is no elastic force acting on it. At the time $t = 0$ the body is hit such that it obtains the speed $v(t = 0) = -v_0$ and starts oscillating without any damping. The body is moving in the horizontal plane without any friction.



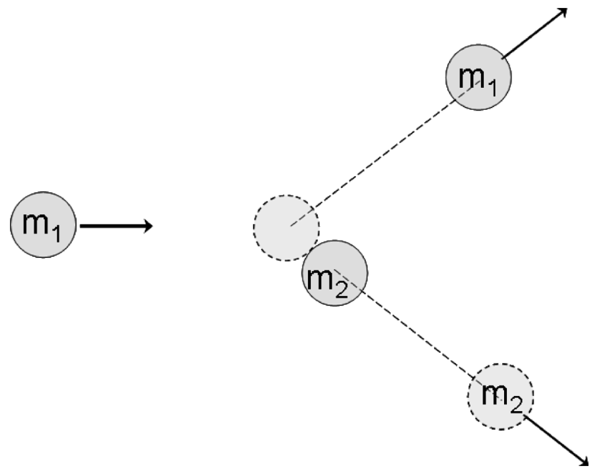
   (a) Derive the equation of motion.

   (b) With which frequency f (careful: not ω!) does the body oscillate? Use the values $m = 2$ kg und $k = 300$ Nm^{-1}.

   (c) Determine the position x of the body as a function of t, that is, solve the equation of motion.

2. **Collision in two dimensions**
   Two repelling magnetic disks collide in two dimensions on an air-cushion table. The disks move frictionless on the table. Disk 1 has a mass of $m_1 = 2.0\,\text{kg}$ and has a velocity of $\vec{v}_1 = \begin{pmatrix} 4 \\ 0 \end{pmatrix}$ m/s when it hits disk 2 which is initially at rest. After the collision the disks have the velocities

$$\vec{v}_1{}' = \begin{pmatrix} 1.5 \\ 1 \end{pmatrix} \text{m/s} \quad \text{and} \quad \vec{v}_2{}' = \begin{pmatrix} 1.25 \\ -0.5 \end{pmatrix} \text{m/s}.$$



(a) What is the mass m_2 of disk 2?

(b) Compute the velocity of the centre-of-mass.

3. Alternating current generator

An alternating current generator consists of a flat, rectangular coil with 100 turns, enclosing an area of $A = 10\,\text{cm}^2$. The coil rotates with an angular velocity of $\omega = 200\,\text{s}^{-1}$ around an axis in the plane of the coil.

(a) Consider that the coil rotates in a constant magnetic field B_0 which is rectangular with repect to the rotation axis. Which functional form does the induced alternating voltage U_{ind} have?

(b) How large is the amplitude of U_{ind} if the voltage is measured at both ends of the coil, assuming that the magnetic field strength is $B_0 = 0.2\,\text{Vs/m}^2$?

(c) Now the coil is fixed and the enclosed area is perpendicular to the magnetic field $\vec{B}$. The magnetic field strength is changed with a constant gradient dB/dt from a value of $0\,\text{Vs/m}^2$ to $B = 0.2\,\text{Vs/m}^2$ within 0.5 s. Which voltage is observed at the ends of the coil?

4. Compton effect

Gamma-ray photons with an energy of $E_\gamma = 100\,\text{keV}$ are scattered off a tungsten target (Compton scattering).

(a) Which is the wavelength of the scattered γ-rays observed at an scattering angle of $\alpha = 90°$?

(b) Which energy and which direction have the scattered electrons?

(c) Why are x-rays or γ-rays used for observing Compton scattering rather than ordinary light?

5. Half-life and activity

(a) A piece of 1 g of natural potassium shows a β activity of 32.4 decays per second which is due to decays of the longlifed isotope ^{40}K. This isotope has an abundance of 0.012% in natural potassium. Determine the half-life of ^{40}K in years.

(b) In the advanced physics laboratory course a ^{137}Cs source is used which was produced in the founding year of the University of Wuppertal in 1972. The source was made of 20 μg of ^{137}Cs Cl. Which activity did the source have in 1972 and which activity does it have today? The half-life of ^{137}Cs is $T_{1/2}$= 30.1 years. The average atomic mass of chlorine (weighted with the isotopic abundances) is m = 35.45 u.