

**Problem 1** (10 pts)

A mass  $M=1\text{kg}$  is attached to a spring and oscillates with angular frequency  $0.1\text{ rad/s}$ . There is a damping force that is proportional to the speed of the mass. After 10 oscillations the amplitude of oscillation has decreased to  $\frac{1}{2}$  of the initial value because of the damping.

- After how many more oscillations will the amplitude be  $\frac{1}{8}$  of the initial value?
- What would be the angular frequency of oscillation for this mass and spring if there was no damping? Give your answer to 6 significant figures.
- When the mass  $M$  is substituted by a smaller mass  $m$ , it comes to rest without oscillating. What is the largest value of  $m$  for which this occurs? Give your answer in g (grams), to 2 significant figures.

**Problem 2** (10 pts)

A standing transverse wave in a string stretched between two supports has frequency  $2\text{Hz}$ . The mass of the string is  $1.5\text{kg}$  and its tension is  $300\text{N}$ .

- Find the two smallest possible values for the length of this string.
- Assuming the length of this string is the largest of the two values found in (a), find the three lowest frequencies of standing waves in this string.
- When the string is oscillating at frequency  $2\text{Hz}$ , the displacement at a certain point along the string is  $0$  at time  $t=0$  and  $1\text{cm}$  at time  $t=0.1\text{s}$ . What is the displacement of this point at time  $t=0.2\text{s}$ ?

**Problem 3** (10 pts)

A straight rod made of a material of elastic modulus  $10^{11}\text{N/m}^2$  has length  $2\text{m}$ , cross-sectional area  $1\text{cm}^2$  and mass  $1.5\text{kg}$ .

- If a force of  $1000\text{N}$  is applied along this rod, what will be the change in its length? Give your answer in mm.
- Give the speed of propagation of longitudinal waves along this rod, in m/s.
- A longitudinal wave of wavenumber  $k=1\text{cm}^{-1}$  is propagating along this rod. Give the wavelength in cm and frequency in Hz of this wave.
- If the amplitude of the motion of the atoms in this rod when this wave (of part (c)) travels along the rod is  $0.01\text{mm}$ , what is the maximum speed of the atoms?