Homework 1

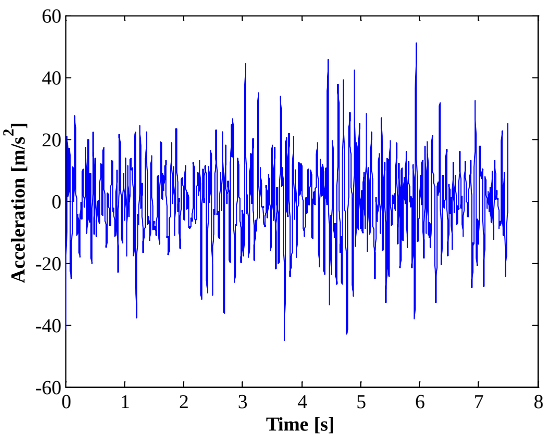
Task 1

Purpose: Learn how to work with real signals.

Level of proficiency required: Intermediate

In order to examine the accelerations that a liquid container experiences, a truck was driven over a bumpy road with an accelerometer attached to the place where the container is connected to the chassis. The accelerometer measured the accelerations in the vertical direction.

The signal from the accelerometer is sampled over a time period of 7.5 seconds. (*This is a real signal from the real truck you see above!*)



The signal can be downloaded from here.

Using the signal, **plot** the velocity and displacement at the measurement point.
Plot the frequency spectrums of the acceleration, velocity and displacement. **Explain** the observed differences between the spectrums.

In addition, **answer** the following questions:

a) Is it possible to determine the first fundamental frequency of the entire truck using this signal? If so, what is it in this case?
b) What is the highest frequency which can be identified from this digitized signal?
c) Knowing the speed of the truck, is it possible to determine the terrain it was driven on using this signal?

Hint: check help to FFT command in MatLab.

Task 2

Purpose: Develop problem solving skills and analytical thinking.

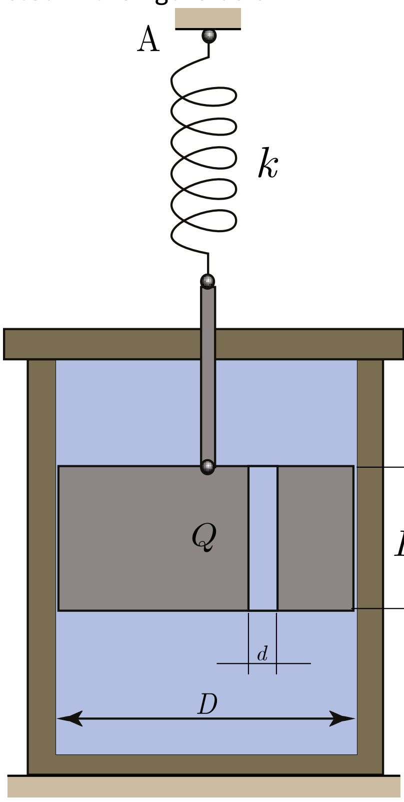
Level of proficiency required: Intermediate

A combination of a hydraulic damper and a spring is widely used in suspension systems (2) as well as in constructions located in seismically active areas (b).

(a)

(b)

We will consider one schematically depicted in the figure below.



The cylinder immersed in a viscous fluid is perforated with holes having a diameter $d = 1\ \mathrm{cm}$. The diameter of the cylinder is $D = 10\ \mathrm{cm}$. The number of holes is $n = 25$. It was initially displaced by a distance of $y_0 = 0.5\ \mathrm{cm}$. Your task is to **determine** the time needed to reduce the amplitude of vibrations by a factor of 2. The spring stiffness $k = 3000\ \mathrm{N/m}$. The weight of the cylinder is $Q = 25\,\mathrm{N}$ and the height is $H = 5\ \mathrm{cm}$. The dynamic viscosity of the fluid is $\mu = 0.06\dfrac{\mathrm{N \cdot s}}{\mathrm{m}^2}$.

You were given the analytical expression for the coefficient that relates the resistance force with the relative velocity of the perforated cylinder has the following expression:

$$\alpha = \frac{8\pi\mu H}{n}\left(\frac{D}{d}\right)^4$$

Before you use it in the solution, **explain** how you can test it experimentally and how you can derive it theoretically. Finally, **calculate** the maximum reaction force in the restraint point A.

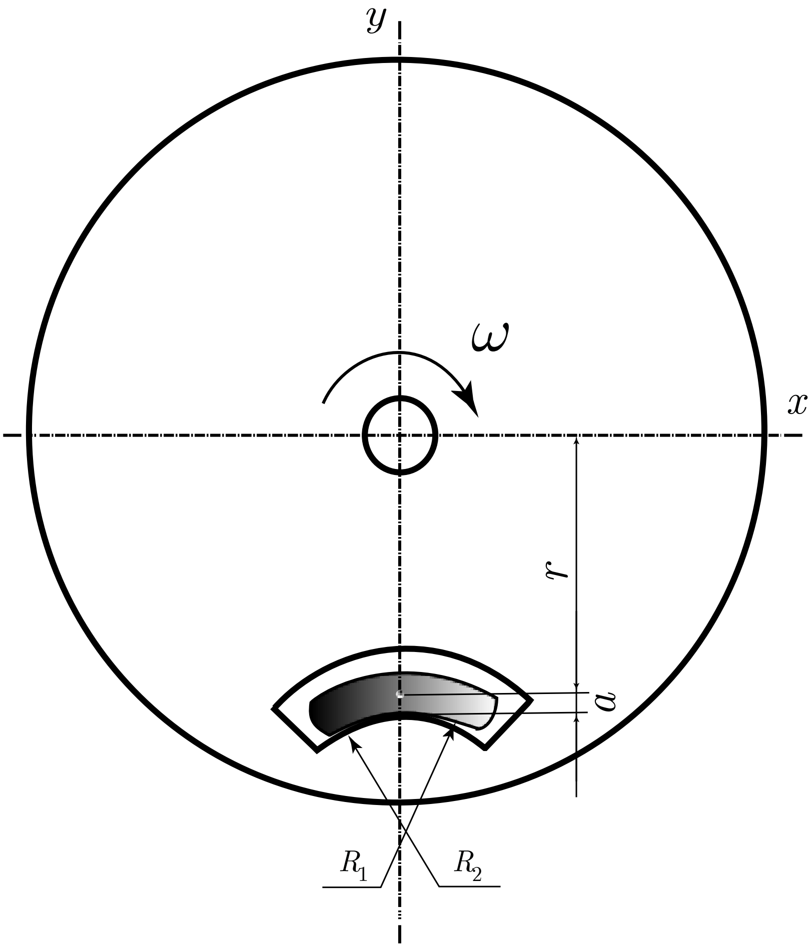
Task 3

Purpose: Develop problem solving skills.

Level of proficiency required: Advanced

Flywheel is a device used to store rotational energy. It is used widely from mechanical watches, cars to really heavy machinery. In order to suppress undesirable vibration, some flywheels are equipped with a pendulum damper. It is a small mass of a special shape which is imbedded into the flywheel and is used to dissipate the energy.

The figure below shows one of possible implementations. The contact surface of the embedded mass has the curvature with a radius R_1 which is greater than the radius of the cavity R_2. At the same time, the difference in radius $R_1 - R_2$ can be considered as small. The distance between the center of the flywheel to the center of the embedded mass is r. The distance between the center of the embedded mass to the point of contact with the flywheel is a. The moment of inertia of the embedded mass is equal to J_c and the mass itself is equal to m.



Your task is to **find** the natural frequency of the embedded mass when the flywheel is:

1) not moving and the gravity is aligned with y-axis;
2) rotating with angular velocity ω and the corresponding centrifugal forces are significantly greater than gravity forces.

State all you assumptions clearly.

Advice: do not postpone this problem until later – it is actually very difficult.