Provide detailed explanation where necessary, additional points may be given for the intermediate steps. Don't forget to indicate your name / matriculation number.

1. To pull a train composed of 10 wagons, locomotive applies a force F. Find the force f exerted by 6-th wagon to the 7-th one. **(1 points)**

2. In an orbital station which is about 400 km above the Earth surface the gravity force is only by about 10% less than on the Earth surface. Why the astronauts do not feel the gravity force, but rather feel weightless? **(1 points)**

3. A magic ball with mass m is attached to a boat moving with a constant acceleration a along a river on the Earth. Find tension T in the string if the drag force f_d exerted by the medium can be neglected (magic ball!). **(1 points)**

4. Two masses lie on a frictionless table and are connected by a spring fixed to both masses. The spring constant is k. The spring is compressed and the masses are fixed by a string as shown in Figure 1(left). How (i) the center of mass and (ii) each mass will move if the string is cut? **(1 points)**

Figure 1: (left) Two masses connected by spring. (right) Rotating disk.

5. Two identical metal balls A and B are filled with liquids having identical densities, but different dynamic viscosities η such that $\eta_A > \eta_B$. Both balls start simultaneously rolling down along an inclined surface. Which of the balls reaches the ground first and why? **(1 points)**

6. After some incident you have landed on an uninhabited island. You find a metal box with: a book on quantum physics, a football ball, a long metal wire, a collection of weights from 1 g to 1 kg, a one liter bier cup, and a broken quantum teleportation device. In order to repair the teleportation unit you need to determine the torsional constant of the metal wire. Suggest how to find it? **(1 points)**

7. A metal ball rotating with the angular frequency ω_0 is placed on a horizontal table with zero translational velocity. The coefficient of friction between the ball and table is f. After some time the ball starts rolling along the table. Find the translational velocity v of the ball when it starts rolling? **(1 points)**

8. Sound wave is found to follow the law $s = A\cos(a^2x + bt)$. Find the wave velocity. **(1 points)**

9. In a cylinder filled with water there are three objects with the densities (i) lower than water, (ii) higher than water, and (iii) identical to water. Where you find these objects, if the cylinder is brought to rotation about the vertical axis? **(1 points)**

10. A disk having mass m and radius R performs n rotations per second about its symmetry axis along vertical direction (see Figure 1(right)). It is placed on a table vertically. The coefficient of kinetic friction between the disk and table is μ_k. Find how many turns N will the disk perform before it stops. **(2 points)**

11. A metal ball falls down vertically onto a massive metal plate orientated at the angle $45°$ to the vertical and collides elastically. Find the ball trajectory $y(x)$ after the collision in the coordinate system with the origin placed into the collision point. The distance between the initial position of the ball and the collision point is h. **(2 points)**

12. A spinning top is made of a hemispherical continuous body (mass M, radius R) and a massless stem of length h as shown in Figure 2(left). At the end of the stem there is a mass m. Find the maximal angle stem can make with the vertical axis so that the top still can return back to the equilibrium vertical position. **(2 points)**

13. At which distance from one of its ends a metal rod with the length L should be pivoted so that its oscillation frequency will be maximal. **(2 points)**

14. A cylindrical vertical tube with diameter D is filled with liquid with dynamic viscosity η and density ρ. A metal ball with diameter d falls down along the central axis of the cylinder with initial zero velocity. Find how the ball velocity will change with time. **(2 points)**

15. Find gravitational potential energy of a planet (i.e potential energy of interaction between all particles within the planet due to the gravity force) with radius R and density ρ. **(3 points)**

16. A soap bubble (radius R, thickness d, soap density ρ) can perform radial oscillations because of the restoring forces caused by the surface tension σ. Calculate the oscillation frequency as a function of R, ρ, and σ (neglect the change of gas pressure inside the soap bubble due to the change of the bubbles volume, i.e. consider the case of small oscillation amplitudes). **(3 points)**

17. An empty spherical glass reservoir is placed in water so that water just covers the sphere as shown in Figure 2(right). At the top there is a cylindrical tube ensuring ambient atmospheric pressure in the reservoir. At the bottom part of the sphere there is a hole with diameter d. Find time for the reservoir to fill with water. **(5 points)**

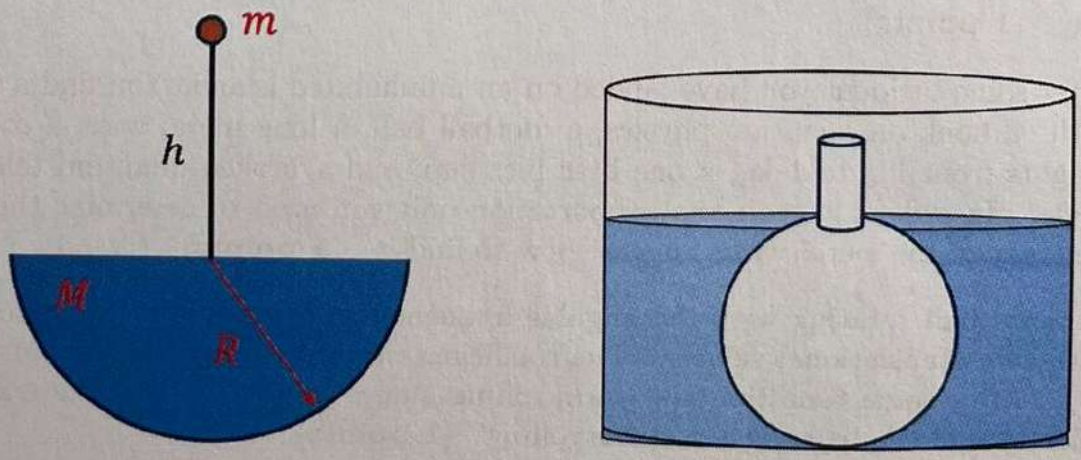

Figure 2: (left) A spinning top. (right) Reservoir under water

Total number of points: **30 points**