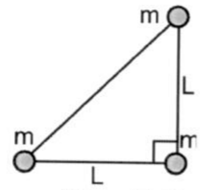
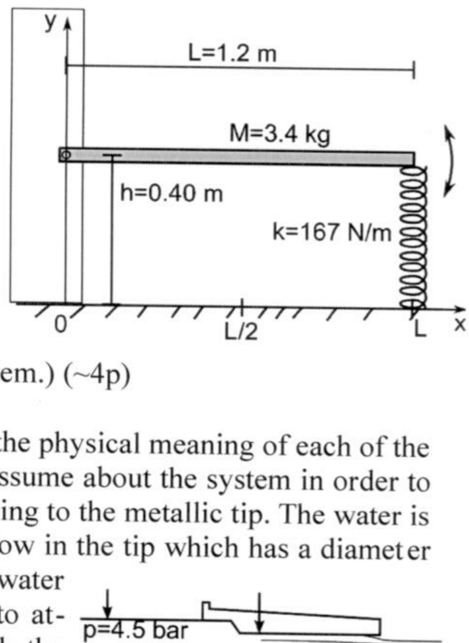
Physics II: Mechanics continuation (FYSP102), Spring 2011 **20.5.2011**
Final Exam (Lecturer: Jan Sarén)

The problem 1 is obligatory. From problems 2—5 you can choose up to 3 problems you answer. If you try all of them, please mark clearly which of them you don't want to be evaluated. The maximum points for the exam is 4*12=48.



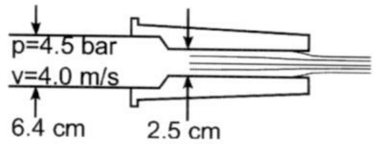
1. (12p) Explain shortly or calculate and answer the questions.
a) Calculate the location of the center of mass for the triangle shown when m=23 g ja L=12 cm. The rods connecting masses are massless. How you can determine the center of mass experimentally? Explain why your method do work?
b) Simple harmonic oscillator. What are needed in order to create such an oscillator? Draw qualitatively the force and the potential energy as a function of displacement. Draw the displacement, velocity and acceleration as a function of time for range $t=0 - 2T$, where T is the period of the oscillator. Assume that at t=0 the displacement is at maximum.
c) What says the Archimedes' principle in your own words.
d) What are decibels? The amplitude of a travelling wave decreace 50% of original. Can you calculate the change in decibels? If you can, calculate the change in decibels?

2. (12p) Two physicist, having masses of about 70 kg each, are running to opposite directions, tangentially towards to the edges of a merry-go-round (carousel) with speeds of 15 km/h. They jump into the merry-go-round simultaneously. The mass of the merry-go-round is 65 kg and the radius is 1.0 m. What is the tangential speed of the physicists right after they are not moving relative to merry-go-round? You can assume that the moment of inertia is $MR^2/2$ for the merry-go-round. Does the kinetic energy conserve in the collision? Explain.



3. (12p) The figure show a rod connected to a rotational axis on its left end. Its moment of inertia is $I=ML^2/3$. The right end is connected to a spring which is touching ground. The rest length (neither stretched nor compressed) of the spring is l_s = 0.50 m. Other information can be found in the figure. **a)** Show that when the system is at rest the rod is horizontal. (~4p) **b)** By pressing and releasing the rod you can get it to oscillate. What is the angular acceleration of the rod when it is in angle θ? (Hint: remember the small angle approximation: $\sin(\theta)\approx\theta$ ja $\cos(\theta)\approx 1$) (~4p) **c)** What is the oscillation frequency? (Hint: compare the answer of part b to the equation of motion of the well known spring-mass system.) (~4p)

4. (12p) **a)** Write the Bernoulli's equation and explain the origin or the physical meaning of each of the terms. (You don't need to derive the equation.) What you have to assume about the system in order to use Bernoulli's equation. (4p) **b)** The figure shows the fire hose ending to the metallic tip. The water is moving to the left. Calculate the pressure and the velocity of the flow in the tip which has a diameter of 2.5 cm. (4p) **c)** According to the figure the diameter of the water stream right after the end of the tip is decreases when it comes to atmospheric pressure. Is it like this in reality? Calculate how much the diameter changes relative to diameter of the tip. (4p)



5. (12p) You have metallic wire weighting 6.2 g/m. You use massless pulley and a weight to set the wire to the tension of 9.81 N so that the length of wire free to vibrate is 24 cm. **a)** At which frequencies you can hear sound when you excite the wire? (4p) **b)** You success to excite the wire so that you hear sound only in one frequency. The frequency is the third lowest possible. Draw the displacement as a function of position at few different moments of time. Let the maximum displacement to be a. (4p) **c)** Write $D(x,t)$ explicitly. (4p)

$$g = 9.81 \text{ m/s}^2 \tag{1}$$
$$G = 6.67 \cdot 10^{-11} \text{ Nm}^2/\text{kg}^2 \tag{2}$$
$$p_{atm} = 101.3 \text{ kPa} \tag{3}$$

$$\theta_1 = \theta_0 + \omega t + {}^1\!/_2\, \alpha t^2 \tag{4}$$
$$\omega_1 = \omega_0 + \alpha t \tag{5}$$
$$\tau_{tot} = I\alpha \tag{6}$$
$$x_{cm} = \frac{1}{M}\int x dm \tag{7}$$
$$I = \int r^2 dm \tag{8}$$
$$I = I_{cm} + Md^2 \tag{9}$$
$$\begin{aligned} E &= K_{rot} + K_{cm} + U_g \\ &= {}^1\!/_2\, I\omega^2 + {}^1\!/_2\, Mv_{cm}^2 + Mgy_{cm} \end{aligned} \tag{10}$$
$$\boldsymbol{L} = \boldsymbol{r} \times \boldsymbol{p} \tag{11}$$
$$\boldsymbol{L} = I\boldsymbol{\omega} \tag{12}$$
$$\boldsymbol{\tau_{tot}} = \frac{d\boldsymbol{L}}{dt} \tag{13}$$
$$F_{mM} = F_{Mm} = GMm/r^2 \tag{14}$$
$$v = \sqrt{GM/r} \tag{15}$$
$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3 \tag{16}$$
$$\begin{aligned} E_{mech} &= K + U_g \\ &= K - \frac{GMm}{r} \end{aligned} \tag{17}$$
$$E_{mech} = K + U_g = -{}^1\!/_2\, U_g + U_g = {}^1\!/_2\, U_g \tag{18}$$
$$g_{surface} = GM/R^2 \tag{19}$$
$$v_{escape} = \sqrt{2GM/R} \tag{20}$$
$$r_{geo} = \left(\frac{GM}{4\pi^2}T^2\right)^{1/3} \tag{21}$$
$$F = -kx \tag{22}$$
$$\omega = \sqrt{k/m} \tag{23}$$
$$\omega = \sqrt{g/L} \tag{24}$$
$$\omega = \sqrt{Mgl/I} \tag{25}$$

$$x(t) = Ae^{-bt/2m}\cos(\omega t + \phi_0) \tag{26}$$
$$E = E_0 e^{-t/\tau} \tag{27}$$
$$\tau = m/b \tag{28}$$
$$\begin{aligned} \omega &= \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}} \\ &= \sqrt{\omega_0^2 - \frac{b^2}{4m^2}} \end{aligned} \tag{29}$$
$$f = T^{-1} = (2\pi)^{-1}\omega \tag{30}$$
$$p = p_0 + \rho g d \tag{31}$$
$$\rho = m/V \tag{32}$$
$$p = F/A \tag{33}$$
$$p_g = p - 1 \text{ atm} \tag{34}$$
$$F_B = \rho_f V_f g \tag{35}$$
$$v_1 A_1 = v_2 A_2 \tag{36}$$
$$p_1 + {}^1\!/_2\, \rho v_1^2 + \rho g y_1 = p_2 + {}^1\!/_2\, \rho v_2^2 + \rho g y_2 \tag{37}$$
$$(F/A) = Y(\Delta L/L) \tag{38}$$
$$p = -B(\Delta V/V) \tag{39}$$
$$\begin{aligned} D(x,t) &= A\sin(2\pi(x/\lambda - t/T) + \phi_0) \\ &= A\sin(kx - \omega t + \phi_0) \end{aligned} \tag{40}$$
$$v = \sqrt{T/\mu} \tag{41}$$
$$\beta = (10 \text{ dB})\log_{10}(I/I_0), \quad I_0 = 1.0 \times 10^{-12} \text{ W/m}^2 \tag{42}$$
$$f_+ = (1 - v_s/v)^{-1} f_0, \quad f_- = (1 + v_s/v)^{-1} f_0 \tag{43}$$
$$f_+ = (1 + v_0/v) f_0, \quad f_- = (1 - v_0/v) f_0 \tag{44}$$
$$A(x) = 2a\sin(kx) \tag{45}$$
$$\lambda_m = 2L/m, \quad m = 1, 2, 3, 4, ... \tag{46}$$
$$\lambda_m = 4L/m, \quad m = 1, 3, 5, 7, ... \tag{47}$$
$$\Delta\phi = 2\pi\Delta r/\lambda + \Delta\phi_0 = m \cdot 2\pi \tag{48}$$
$$\Delta\phi = 2\pi\Delta r/\lambda + \Delta\phi_0 = (m + 1/2) \cdot 2\pi \tag{49}$$
$$D = 2a\cos(\Delta\phi/2)\sin(kx_{ave} - \omega t + (\phi_0)_{ave}) \tag{50}$$
$$A = |2a\cos(\Delta\phi/2)| \tag{51}$$
$$f_{beat} = f_1 - f_2 \tag{52}$$