Physics, Theoretical competition.

Problem 1 (10 points)

One of the ends of the uniform massive rod of length L is connected using a hinge to a vertical rotating axis (fig.1.1). The hinge is such that in the reference frame of the axis the rod can freely move in a certain vertical plane, without any friction in the hinge. The axis is rotating with an angular velocity ω, acceleration of gravity equals **g**.

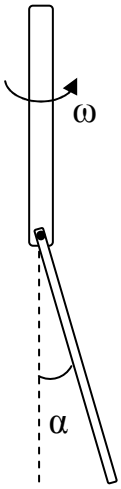

Fig.1.1

1) Calculate the stationary values of the angle α.
2) Analyze the stability of the system for each stationary state.

Suppose that the rod is given a small kick with respect to its stable state.

3) Calculate the period of oscillations.

Problem 2 (8 points)

The stove is used to heat the room, and the temperature in the room is T_1= 17°C, while the temperature outside is T_o= 7°C. It is suggested to use the ideal thermal pump instead, using the reversed Carnot cycle. Degree of efficiency of the engine, used in reverse Carnot cycle is η= 60%. Assuming that the heat exchange between the room and the outside is proportional to the temperature difference, and that the engine uses the same amount of fuel per unit time as the stove, calculate the temperature in the room, if

1) engine is located outside of the room
2) engine is located inside the room.

Problem 3 (12 points)

Given a ring of radius R with a current I flowing in it.

1. Calculate the magnetic field at point O_1 located on the axis of the ring. The total angular span of the ring at point O_1 equals 2α. (See Fig.3.1)

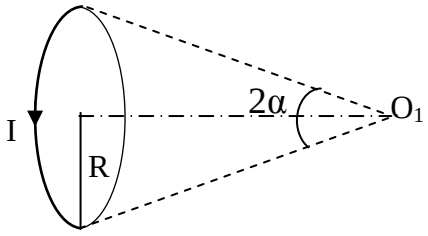

Fig.3.1

The solenoid of radius R and length l consists of N coils, distributed uniformly. The current through the solenoid equals I.

2. Find the magnetic field on the axis of the solenoid at the point, from which the angular span of the ends of solenoid equals 2α and 2β. (See Fig.3.2)

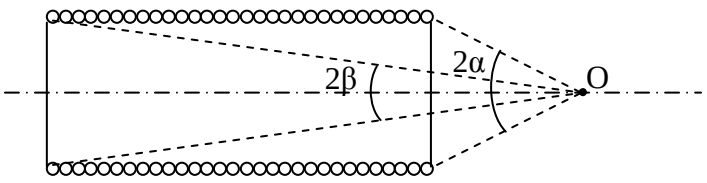

Fig.3.2

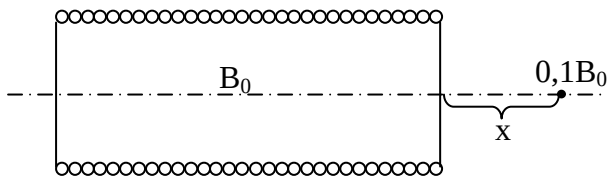

Fig.3.3

3. In the following we assume that $\ell >> R$.
   a) Calculate the magnetic field B_0 inside the solenoid far away from its ends.
   в) Find the distance x, for which $B=0.1 \cdot B_0$ (See Fig.3.3)
   c) Calculate the inductance of the coil L, assuming that magnetic field inside the solenoid far away from its ends is uniform.

Magnetic bullet is moving along the axis of the solenoid. Solenoid is connected to a capacitor *C*. Magnetic moment of the bullet *M* is parallel to the axis of the solenoid. We will neglect the change of the velocity of the bullet.

4. a) Write the condition, that the time it takes the bullet to pass the region of non uniform magnetic field is much smaller than the period of oscillations in LC circuit. Assume in the following, that this condition is always satisfied.
   b) Find the values of the bullet velocities υ, such that the amplitude of oscillations in LC circuit after the bullet passes the solenoid is maximal.
   c) What is the value of the current oscillation amplitude I_{max} for this case? Draw the graph of $I(t)$.
   d) Prove that the magnetic force acting on a bullet equals $M\frac{\partial B}{\partial x}$ and is parallel to the axis of the solenoid.

   Comment:
   You may consider the bullet to be a small ring of area S_0,with a current I_0, and $M=S_0I_0$.
   In the theory of the magnetism the following theorem is proven: *If one denotes the flux of the magnetic field created by the first contour through the second contour as* $L_{12}I_1$, and *the flux of the magnetic field created by the second contour through the first contour as* $L_{21}I_2$,*then* $L_{12}=L_{21}$. *It is assumed that the positive direction of the flux is consistent with the positive direction of the current in each contour* .