PHYS 113 - FINAL EXAM
4 January 2006

Name and Surname:
Student ID:
Department:
Signature:

1. Consider an ideal gas enclosed in a cylinder of volume V and cross sectional area A. On top of the gas, there is a frictionless piston of mass M. Initially the system is at rest,i.e., the weight of the piston is balanced by the pressure of the gas. If the piston is pushed down slightly (much smaller than the height of the cylinder), write down the equation governing the subsequent motion of the piston. Describe the motion. (ignore the variation of the pressure of the gas due to the weight of the gas particles; ignore the atmospheric pressure; assume that the temperature is constant during the process)

2. Consider the following $P - V$ diagram of a process involving an ideal gas. The gas is first expanded isothermally from (P_1, V_1) until (P_2, V_2), then it is let to expand adiabatically from (P_2, V_2) until (P_3, V_3), in the third stage it is compressed such that the state of the gas traces a straight line from (P_3, V_3) until (P_1, V_1). Calculate the work done and the efficiency of the engine.

3. Show that the Kelvin-Planck statement of the second law of thermodynamics, i.e.:

   An engine operating in a cycle cannot transform heat into work without some other effect on its environment

   and the Clausius statement:

   An engine operating in a cycle can not transfer heat from a cold reservoir to a hot reservoir without some other effect on its environment

   are equivalent.

4. Consider a circular loop rotating vertically at a constant angular velocity ω in a uniform gravitational field. If there is a bead of mass m on the loop which can move freely along the loop, calculate the angle that the line connecting the bead to the center of the loop as a function of the angular velocity ω of the loop.

5. Consider a bucket filled with a liquid of mass density ρ. On the side of the bucket, there is a small hole at a distance h from the top level of the liquid. Outside the bucket, there is a square plate of width L covering the hole such that the center of the square coincides with the hole on the bucket. Calculate the angle the plate makes with the side of the bucket as water gets out of the bucket. (Ignore the variation of the level of the liquid, i.e. keep h constant, the liquid makes elastic collisions with the plate and the angle that the water beam makes with the perpendicular to the plate is the same before and after collision).

You can use the following relations:

$$(1+x)^n \simeq 1 + nx + \frac{1}{2}n(n-1)x^2 \qquad (1)$$