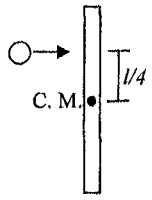
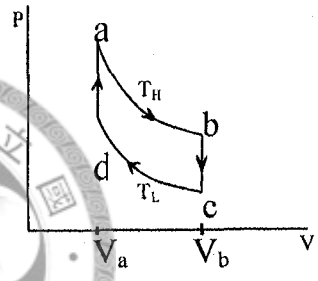
1. A thin uniform rod of mass M and length l rests on a frictionless table. A clay ball of mass m with speed v hit the rod at a point $l/4$ from the center of mass of the rod. The ball sticks to the rod. After the collision, (a) what is the speed of the center of the mass of the clay-rod system? (b) what is the rotational inertia of the clay-rod system if the rotation axis is through the center of mass and perpendicular to the plane. (c) with what angular velocity does the system rotate about its center of mass? (15%)



2. The van der Waals equation of state is $(P+\frac{a}{(V/n)^2})(\frac{V}{n}-b)=RT$, where P is the pressure, V the volume, T the temperature, n the number of moles, a, b, and R constants. Please find the critical temperature and pressure. The critical point is defined as the inflection point of the P-V diagram where the first and second derivatives are zero. (15%)

3. The Stirling cycle is shown in the figure. Find the efficiency of the cycle in terms of the parameters shown, assuming a monatomic gas as the working substance. The processes ab and cd are isothermal whereas bc and da are at constant volume. (15%)



4. A nonconducting sphere of radius r_0 carries a total charge Q distributed non-uniformly throughout its volume. The charge density is proportional to the distance r from the center of the sphere. Determine the electric potential as a function of r for (a) $r > r_0$ and (b) $r < r_0$, (c) Plot V verse r, and E versus r. (20%)

5. When the Sun became hot and luminous long ago, it is believed that it ejected dust particles and individual atoms out of the solar system by radiation pressure. Calculate how small the dust particle (or the diameter of the particle, R) had to be in order to be ejected out of the solar system. Use the following parameters: ρ as the density of the particle, M_s the mass of the sun, P_s the average power output of the sun. (10%).

6. A beam of partially polarized light can be considered to be a mixture of polarized and unpolarized light. Suppose we send such a beam through a polarizing filter and then rotate the filter through $360°$ while keeping it perpendicular to the beam. If the transmitted intensity varies by a factor of 3.0 during the rotation, what fraction of the intensity of the original beam is associated with the beam's polarized light? (15%)

7. Suppose a nonconducting rod of length l carries a uniformly distributed charge Q. It is rotated with angular velocity ω about an axis perpendicular to the rod at one end. Find the magnetic dipole moment of this rod. (10%)