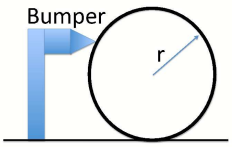
GRADUATE WRITTEN EXAMINATION, August 2009

Short Problems *Best 10 of 12*

1. What is the interaction energy between two parallel electrostatic dipoles,with dipole moments $\vec{p}_1$ and $\vec{p}_2$ respectively, separated by a distance d? Assume the line joining the dipoles is perpendicular to the direction of the dipoles.

2. A radioactivity counter has a precisely known mean expected background rate of 63 counts/min. In the presence of a test sample a technician measures 94 counts in one minute. Roughly, how long does the technician need to take data in order to quote the sample rate with an uncertainty of 10%?

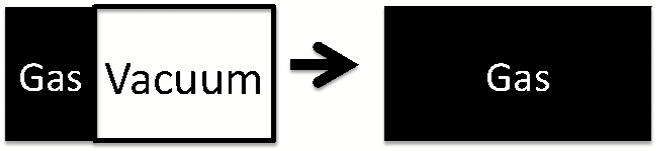
3. The bumpers of a billiard table are designed so that there is no horizontal reaction force that the table surface exerts on the ball during a rolling collision. What will be the height of the bumpers with respect to the radius of the billiard ball? The moment of inertia for a billiard ball is $I = \frac{2mr^2}{5}$.



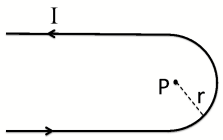
4. What is the value of the matrix element $< j\prime, m\prime|[J^+, J^-]|j, m >$?

5. Assume a football player (American football) can throw horizontally more easily than vertically. The initial speed of the football varies as $v_0 cos(\theta)$ where θ is the initial elevation angle. What elevation angle achieves the maximum horizontal distance? Neglect air resistance.

6. One mole of an ideal gas is confined to one third of a thermally insulated container (see figure). The membrane ruptures and the gas freely expands. What is the change in entropy?



7. A long wire with current I is bent so that it forms a long U shape. Find the expression for the magnetic field ($\vec{B}$) at the point P, which is at the center of the semi-circle. Clearly indicate the units and your system of units.

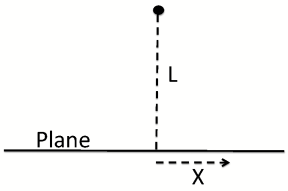


8. A number, N, of Maxwell-Boltzmann particles are distributed among 4 energy states: The energy of the nth state is nkT where n=0,1,2 and 3. What is the energy of the system as a function of temperature?

9. Matrix A is Hermitian and unitary. Derive the possible eigenvalues.

10. Suppose the electron is 100 times more massive than it's known mass. What would be the energy of a radiated photon in a hydrogen atom when the electron transitions from the first excited state to the ground state? What would be the radius of the first Bohr orbit?

11. A charge q is a distance L from a conducting grounded plane (infinite in extent). Find an expression for the charge density of the plane as a function of the distance x in the figure. The variable x represents the radial distance from the point on the plane that is directly below the charge.



12. Derive the Ideal Gas Law for a 2-dimensional gas. It may be helpful to consider the average force exerted by a molecule on the wall of a container.