PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part B, 14 August 2003, 14:00 - 17:00

B1. (10 points) Twelve wires, each of resistance r, are connected to form the edges of a cube. Calculate the effective resistance R of this network across a body-diagonal of the cube.

B2. A block of wood of (initial) mass M slides without friction on a horizontal surface. A machine gun shoots a continuous horizontal stream of bullets into the block. The bullets, which each have mass m, leave the machine gun at a rate of n bullets per second and with muzzle speed v_0. You may assume that n is very large and that m is correspondingly small. That is, you may take the limit $n \to \infty$ with $nm = \mu$ fixed. You may also neglect the effects of gravity and air friction on the motion of the bullets. The block absorbs the bullets and thus becomes heavier with time. The block is at rest at $t = 0$. At time t, let $m(t)$ be the mass of the block including all the bullets it has absorbed up to that point, and $v(t)$ its velocity in the direction away from the machine gun.

(a) (5 points) Show that

$$\{v_0 - v(t)\}\, m(t) = v_0\, M$$

at all times.

(b) (3 points) Solve for the motion of the block, i.e. obtain the distance $x(t)$ traveled by the block as a function of time.

(c) (2 points) What is the acceleration of the block at $t = 0$?

B3. A molecule of hydrogen in its ground state can exist in two forms: ortho-hydrogen where the nuclear spins are parallel, resulting in a net spin; and para-hydrogen where the nuclear spins are antiparallel, resulting in no net spin. The ortho form of hydrogen has three spin states all of the same energy $\epsilon > 0$, and the para form has one state of zero energy. The hydrogen molecules form a solid made up of N molecules, with each molcule distinguishable from the rest by being localized on a lattice site. Assume that the spins of neighboring molecules couple very weakly. The solid is thermally isolated and has a fixed energy $U = n\epsilon$, where n is the number of molecules in the ortho state.

(a) (4 points) What is the entropy of this system?

(b) (2 points) Obtain an expression for the temperature of this system.

(c) (4 points) How does the number of molecules in the para state vary with temperature?