FALL 2005: PHYSICS DEPARTMENTAL EXAM
SECTION I

MECHANICS

1. A brick of mass M is suspended between two walls by two springs each of spring constant k. The right wall is rigid; the left wall is the outer side of a movable piston that seals a thermally-isolated tank of gaseous Krystophite from the Planet Zartron. A Bunsen burner underneath the Krystophite supplies it with 20 Watts.

From the brick hangs a massless bungee cord, the end of which is attached to the left ankle of a dead frog of mean density ρ. A double-pendulum hangs on an inextensible rope from the frog's right big toe. The first pendulum is a solid disc of cheese. The second pendulum is a hollow sphere, inside of which resides a hamster who runs at a constant nonrelativistic angular velocity ω on an aluminum wheel of radius R.

The frog has been dead for two days and the air humidity has remained constant at 49% since then. The hamster is pregnant.

By solving for the most general equation of state for gaseous Krystophite, find the LaGrangian of the system.

2. How does your answer to question #1 change if the hamster's linear velocity $v = 8c/9$ and the rigid right wall is now a melting glacier?

ELECTRICITY AND MAGNETISM

3. Using Maxwell's equations for dielectric media, briefly explain why sticking a fork into an electrical outlet when you were seven was a stupid thing to have done.

4. What about a spoon? Would that be stupid? Why or why not?

QUANTUM

5. A photon is incident upon a hydrogenic atom in the thin atmosphere surrounding the Planet Zartron. The atom's electron is excited above the ground state but is not ejected from the atom. The subsequent minute change in the atom's dipole moment causes a disturbance in the far-field vector potential, way up in space beyond the planet's moons.

Meanwhile, back at the Palace there is trouble. Zartron's evil neighbor Yhsqref has felt this far-field disturbance and interpreted it as an intentional intrusion into their personal space. Their leader has threatened to bombard Zartron with no fewer than 10^{51} anti-protons, with the aim of annihilating the planet.

Fortunately, in the nick of time that upstart hydrogenic atom that had kicked off all these shenanigans spontaneously decays to its ground state, and the far-field dipole approximation for the vector potential readjusts to its initial form.

What, if anything, was conserved during this process?

6. A spin-1/2 particle is initially spin-up along the z-axis. It is then directed through a Stern-Gerlach apparatus and emerges a time t later.

What is the probability that it is still spin-up from the reference point of a dead frog hanging by his left ankle from a massless bungee cord?

STATISTICAL MECHANICS

7. How do you feel about fugacity? Be honest.

8. Write a song about fugacity. Be prepared to sing it a capella for the exam committee.

MATH

10. A double-pendulum attached to a dead frog's toe suddenly falls under its own weight, taking the frog's toe with it. How many toes does the frog have left? Be sure to state clearly any assumptions you make in obtaining your answer.