PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part D, 20 August 2001, 14:00 - 17:00

D1. Using the Heisenberg uncertainty principle, demonstrate that:

(a) (6 points) electrons are unlikely to be primary constituents of atomic nuclei ($R \sim 10^{-14}$ m);

whereas

(b) (4 points) their existence within atoms ($R \sim 5 \times 10^{-11}$ m) is plausible.

D2. An athlete can throw a javelin 60 m from a standing position. Neglect air resistance and the height of the athlete.

(a) (4 points) If she can run at a speed of 10 m/s, how far can she hope to throw a javelin (with mass 500 g) while running? At what angle above the horizontal should she throw the javelin?

(b) (6 points) How far down a slope inclined at 10° with respect to the horizontal can this same athlete throw the javelin from a standing position? At what angle relative to the horizontal should she throw the javelin in this case?

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D3. A two-dimensional rotor has a moment of inertia I and dipole moment $\vec{P}$. In an external electric field $\vec{E} = E_x\,\hat{x}$, the interaction energy is

$$\mathcal{H}' = -\vec{P} \cdot \vec{E} \ ,$$

which can be regarded as a perturbation to the original Hamiltonian

$$\mathcal{H}_0 = \frac{L_\phi^2}{2\,I} \ .$$

(a) (3 points) Obtain the eigen-energy and eigenfunction of the unperturbed Hamiltonian $\mathcal{H}_0$.

(b) (3 points) Find the first-order perturbation energy to $\mathcal{H}_0$.

(c) (3 points) Find the second order perturbation energies and eigen-functions for the ground state and the first excited state.

(d) (1 point) Discuss the angular dependence of the probability function. Does the rotor prefer to align with the external field, in the ground state, or in the first excited state?