1. (10%)

   (a) List at least four differences between waves and particles.

   (b) What are linear, circular, and elliptical polarizations?

2. (20%) In an isolated system, there are two metals with masses m_1 and m_2, mass specific heat c_1 and c_2, and temperature T_1 and T_2. These two metals are brought together and eventually reach thermal equilibrium. Prove that the two metals have the same final temperature. Compute the final temperature and entropy change of the total system.

3. (20%) Suppose a solid uniform disk of radius R is given an angular speed ω_i about an axis through its center and lowered to a horizontal surface and released. Assume that the coefficient of friction between disk and surface is μ. (a) Find the time interval before pure rolling motion occurs. (b) Find the distance the disk travels before pure rolling occurs.

4. (10%) A dielectric slab of thickness d and dielectric constant κ is inserted in the middle of a parallel-plate capacitor of plate separation D. What is the new capacitance of the capacitor, given that the area of each plate is A?

5. (20%)

   (a) What are the dimensions of ϵ_0, the permittivity of free space, and μ_0, the permeability of free space, respectively? Show that the quantity $\frac{1}{\sqrt{\mu_0\epsilon_0}}$ has the dimension of speed.

   (b) If the electric field of an electromagnetic plane wave is given by

$$\vec{E} = E_0 \cos(kz + \omega t)\hat{j}$$

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where $\hat{j}$ is a unit vector in the y-direction, what is the magnetic field $\vec{B}$ for this plane wave?

(c) What is the energy density for the plane wave in (b)?

(d) What is the Poynting vector (energy flux) $\vec{S}$ for the plane wave in (b)?

6. (20%) Explain the following terms:

(a) Beta decay

(b) Fermi energy

(c) Diamagnetism

(d) Twin paradox

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