

Crossing Examination Paper
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Electrodynamics I and Electrodynamics II (100 points)

1. A uniform spherical charge distribution has a radius R and a uniform charge distribution ρ . Find (i) electric field inside and outside of this system (ii) potential inside and outside of this system. [50 points]
2. Calculate the capacitance of a capacitor of two coaxial cylinders of height h and radii r_1 and r_2 . Neglect the stray fields at the edges. [50 points]

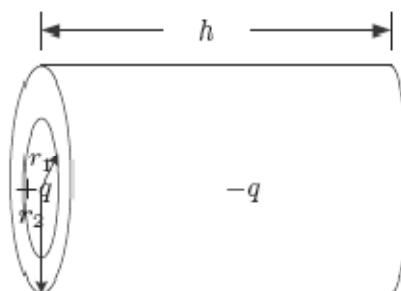


Figure 1:

Quantum Mechanics I and Quantum Mechanics II (100 points)

3. A particle of mass m moving in one dimension has a potential $V(x)$ which is a shallow square well near the origin:

$$V(x) = \begin{cases} -V_0 & |x| < a \\ 0 & |x| > a \end{cases}$$

where V_0 is a positive constant. Derive the eigenvalue equation for the state of lowest energy, which is bound state (see Figure 2)[50 points]

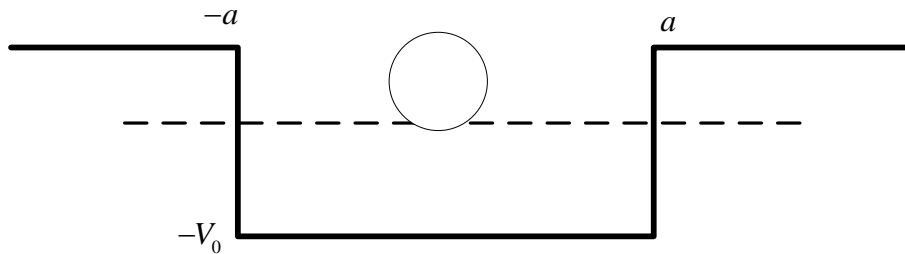


Figure 2:

4. A particle of mass m is coupled to a simple harmonic oscillator in one dimension. The oscillator has frequency ω and distance constant $x_0^2 = \hbar / m\omega$. At time $t = 0$ the particle's wave function $\Psi(x, t)$ is given by

$$\Psi(x, 0) = \frac{e^{-x^2/2\sigma^2}}{(\pi\sigma^2)^{1/4}}$$

The constant σ is unrelated to any other parameters. What is the probability that a measurement of energy at $t = 0$ finds the value of $E_0 = \hbar\omega / 2$? [50 points]

Thermodynamics and Statistical Mechanics (100 points)

5. Find the efficiency of the Joule cycle, consisting of two adiabats and two isobars (see Figure 3). Assume that the heat capacities of the gas C_p and C_v are constant.[50 points]

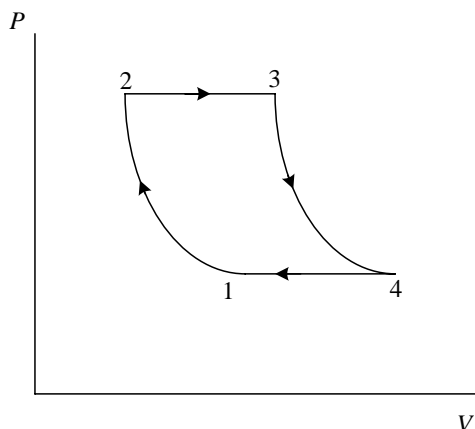


Figure 3:

6. Consider a monatomic ideal gas of total \tilde{N} molecules in a volume \tilde{V} . Show that the probability, P_N , for the number N of molecules contained in a small element of V is given by the Poisson distribution

$$P_N = \frac{e^{-\langle N \rangle} \langle N \rangle^N}{N!}$$

where $\langle N \rangle = \tilde{N}V / \tilde{V}$ is the average number of molecules found in the volume V . [50 points]

Modern Physics (Special Relativity Part) and Waves and Vibrations (100 points)

7. An electron e^- and a positron e^+ each of mass m_e bound with binding energy ε_b in positronium, annihilate into two photons. Calculate the energy, momentum, velocity, and frequency of the photons. [50 points]
8. A mass on a horizontal spring (cf. Figure 4) m has a value of 0.80 kg and the spring constant k is 180 N m⁻¹. At time $t = 0$ the mass is observed to be 0.04 m further from the wall than the equilibrium position and is moving away from the wall with a velocity of 0.50 m s⁻¹. Obtain an expression for the displacement of the mass in the form $x = A \cos(\omega t + \varphi)$, obtaining numerical values for A , ω and φ . [50 points]

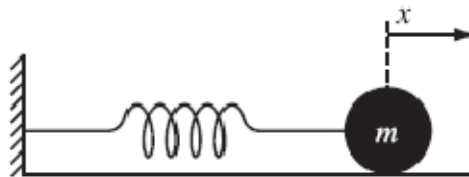


Figure 4:

Classical Mechanics I and Classical Mechanics II (100 points)

9. Consider a solid cylindrical rolling without slipping on an inclined plane (Figure 5). Determine the equation of motion with Newtonian method. [50 points]

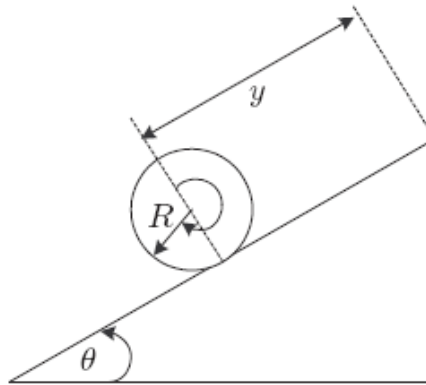


Figure 5:

10. A mass m is suspended by a spring with spring constant k in the gravitational field. Besides the longitudinal spring vibration, the spring performs a plane pendulum motion (Figure 6). Find the Lagrangian, derive the equations of motion, and discuss the resulting terms. [50 points]

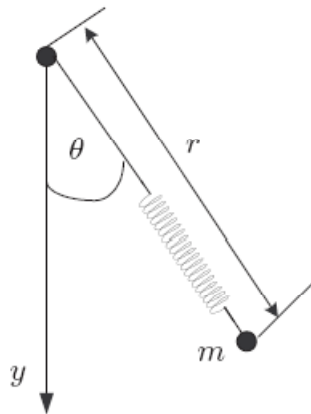


Figure 6:

‘The scientist does not study nature because it is useful, he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living.’

Jules Henri Poincaré