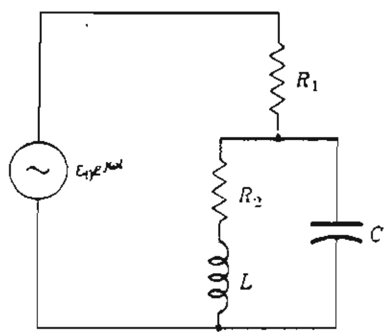
Department of Physics

Preliminary Examination. Wednesday, January 3, 1990

Electricity, Magnetism, and Optics

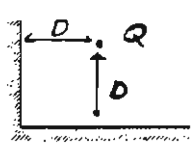
1. Suppose a uniform magnetic field points in the x-direction and, also, a uniform electric field points in the z-direction. A particle of charge q is released at rest from the origin. What path will the particle follow? Write down the equations of motion of the particle and solve for its trajectory.

2. Make a plot of the power dissipated and of the relative phase between the voltage and the current as a function of frequency for the following circuit.

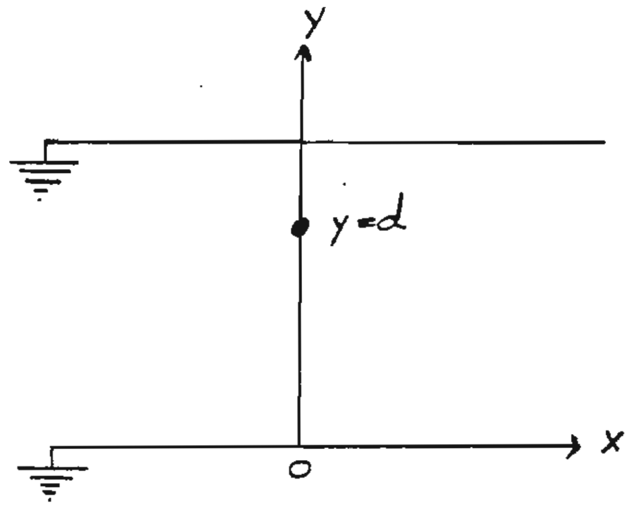


Derive expressions for the power and the relative phase when the frequency is $1/\sqrt{LC}$.

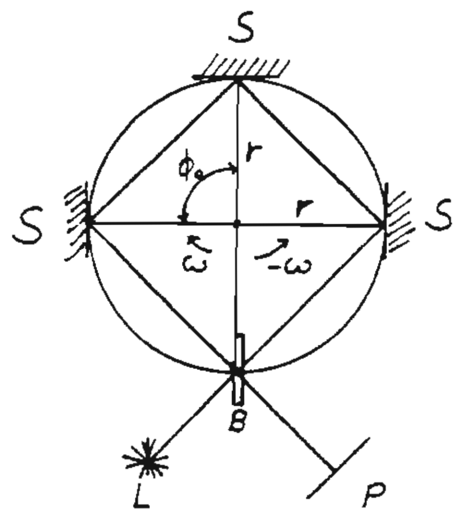
3. Make a plot of the surface charge distribution induced by a positive charge Q placed equidistance "D" away from the conducting surface shown below.



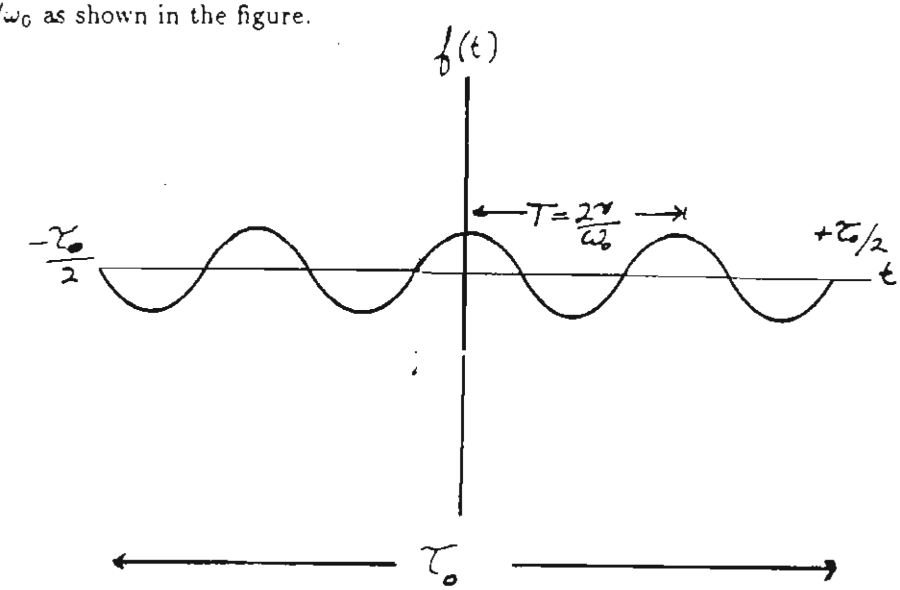
4. What is the potential between two parallel grounded conducting plates at $y = 0$ and $y = a$ as shown below, with a line charge parallel to the z-axis at the point $(0, d)$? Let λ be the charge per unit length. Solve this problem by using a Fourier series. Do not solve the point-charge problem first, but solve the line-charge problem directly.



5. As shown in the figure, a partially reflecting plate B and three mirrors S are mounted at the corners of a square which is inscribed in a disk. The plate B is mounted in a radial position and the mirrors S are mounted tangentially to the disk. The monochromatic light source L and photographic plate P are also rigidly attached to the disk. Light emitted by L is split into two beams traveling around the square in opposite directions which interfere at P. If the disk is made to rotate in the clockwise direction with an angular frequency ω, the interference fringes will appear at one position. If the disk is rotated at $-\omega$ in the opposite direction, the position of the fringes will shift by an amount Δz, where Δz corresponds to a fractional multiple of the wavelength of the light. Derive an expression for Δz.



6. Consider a pulse of light with a spatial extension $l_0 = c\,\tau_0$ in the form of a finite harmonic wave train of lifetime τ_0 and period $2\pi/\omega_0$ as shown in the figure.



Derive an expression for the frequency spectrum of this pulse. Use this to find the spectral bandwidth of a 20 picosecond pulse. Also find the temporal width of a 2 GHz spectral width pulse.