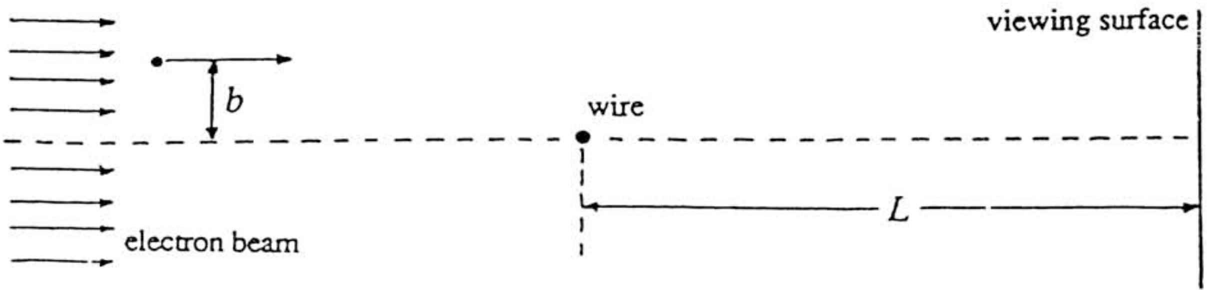
Theoretical Problem 3

ELECTRON BEAM

An accelerating voltage V_0 produces a uniform, parallel beam of energetic electrons. The electrons pass a thin, long, positively charged copper wire stretched at right angles to the original direction of the beam, as shown in the figure. The symbol b denotes the distance at which an electron would pass the wire if the wire were uncharged. The electrons then proceed to a screen (viewing surface) a distance L ($\gg b$) beyond the wire, as shown. The beam initially extends to distances $\pm b_{max}$ with respect to the axis of the wire. Both the width of the beam and the length of the wire may be considered infinite in the direction perpendicular to the paper.



The charged wire extends perpendicularly to the plane of the paper. The sketch is not to scale.

Some numerical data are provided here; you will find other numerical data in the table at the front of the examination:

radius of wire = r_0 = 10^{-6} m

maximum value of b = b_{max} = 10^{-4} m

electric charge per unit length of wire = q_{linear} = 4.4×10^{-11} C m^{-1}

accelerating voltage = V_0 = 2×10^4 V

length from wire to observing screen = L = 0.3 m.

Note: For parts 2 - 4, make reasonable approximations that lead to analytical and numerical solutions.

1) Calculate the electric field **E** produced by the wire. Sketch the magnitude of **E** as a function of distance from the axis of the wire.

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2) Use classical physics to calculate the angular deflection of an electron. Do this for values of the parameter b such that the electron does not strike the wire. Let θ_{final} denote the (small) angle between the initial velocity of the electron and the velocity when the electron reaches the viewing surface. Hence, calculate θ_{final}.

3) Calculate and sketch the pattern of impacts (i.e., the intensity distribution) on the viewing screen that classical physics predicts.

4) Quantum physics predicts a major difference in the intensity distribution (relative to what classical physics predicts). Sketch the pattern for the quantum prediction and provide quantitative detail.