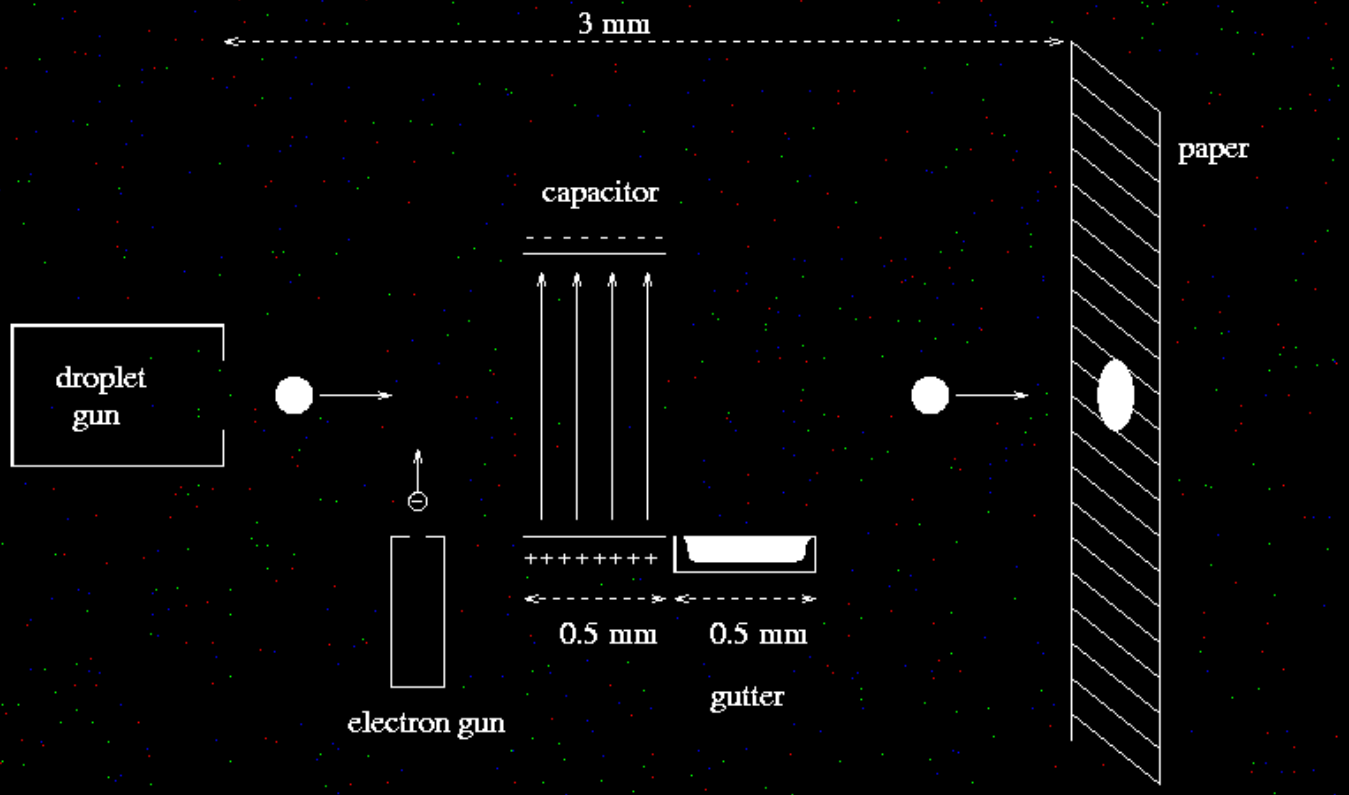
Simple Calculations on Mathematical Model of an Ink Jet Printer

Question: The nozzle (also called the ink gun) of an ink jet printer produces small ink droplets, which are charged negatively by an electron gun. The charged ink droplets then pass through an electric field created between two parallel plates (called the deflecting capacitor). Controlling the magnitude of this electric field through computerized means, the charged ink droplets are given various deflections to direct them to the correct position on a page.



1) The electron gun must give the droplet a charge of about $q = 1.9 \times 10^{(-10)}$ Coulombs in order to permit the capacitor to deflect it. The electron gun can shoot electrons at a droplet as it moves past the gun in order to give it a negative electric charge. How much current does it take?

Given: Diameter of ink droplets (d) = 70 μm
Speed of droplets (v) = 20 m/sec

Solution: Electrons fired straight out of the gun will hit the droplet during a window of time (T).

T = Diameter of droplet (d) ÷ Speed of droplet (v)
= $(70 \times 10^{(-6)} / 20)$ sec
= $3.5 \times 10^{(-6)}$ sec

Current of beam, I = Electric charge to be given (q) ÷ T
= $[1.9 \times 10^{(-10)} \div 3.5 \times 10^{(-6)}]$ A
= 54 μA

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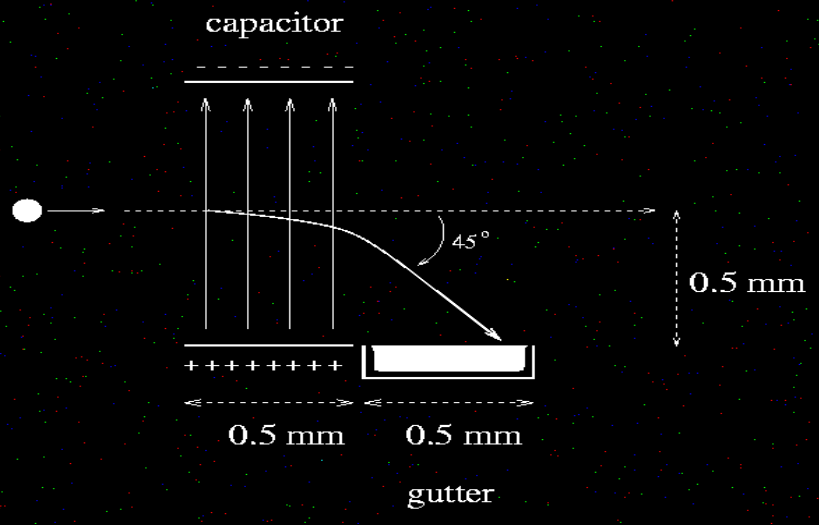
2) The ink gun sends a steady stream of droplets towards the paper. If they all reached the paper, they would leave a solid black area. In order to form letters, numbers, and images, the printer must somehow deflect the ink droplets. The capacitor performs this task. Now suppose we are required to deflect an ink droplet towards the positive plate by 45°. Then what potential difference should be applied between the plates.

Given: droplet mass (M) = $1.13 \times 10^{(-10)}$ kg
droplet charge (q) = $1.9 \times 10^{(-10)}$ C
horizontal speed (v) = 20 m/s
Length of the plates of the capacitors (L) = 0.5 mm
Distance between the plates of capacitor (H) = 1.0 mm



Solution: Initial horizontal speed = 20 m/s

Initial vertical speed = 0 m/s

As finally the droplet moves at 45^{o} with the initial velocity, so

Final horizontal speed = 20 m/s

Final vertical speed = 20 m/s

Change in vertical speed = (20 – 0) m/s = 20 m/s

Time for which the droplet stays inside capacitor is,

t = length of capacitor (L) ÷ horizontal velocity of droplet

t = (0.5 mm)/(20 m/s) = $2.5 \times 10^{(-5)}$ seconds

So vertical acceleration, a = 8×10^{5} m/s^{2}

Now, electric force, q × E = m × a

or, E = 4.8×10^{5} Volts/meter

So, potential difference between plates is,

V = E × H

= (4.8×10^{5} V/m) × (0.001 m) = 480 volts

For more detailed solution please vist the source:
Physics of an Ink-Jet Printer

PH1213 Presentation Question
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