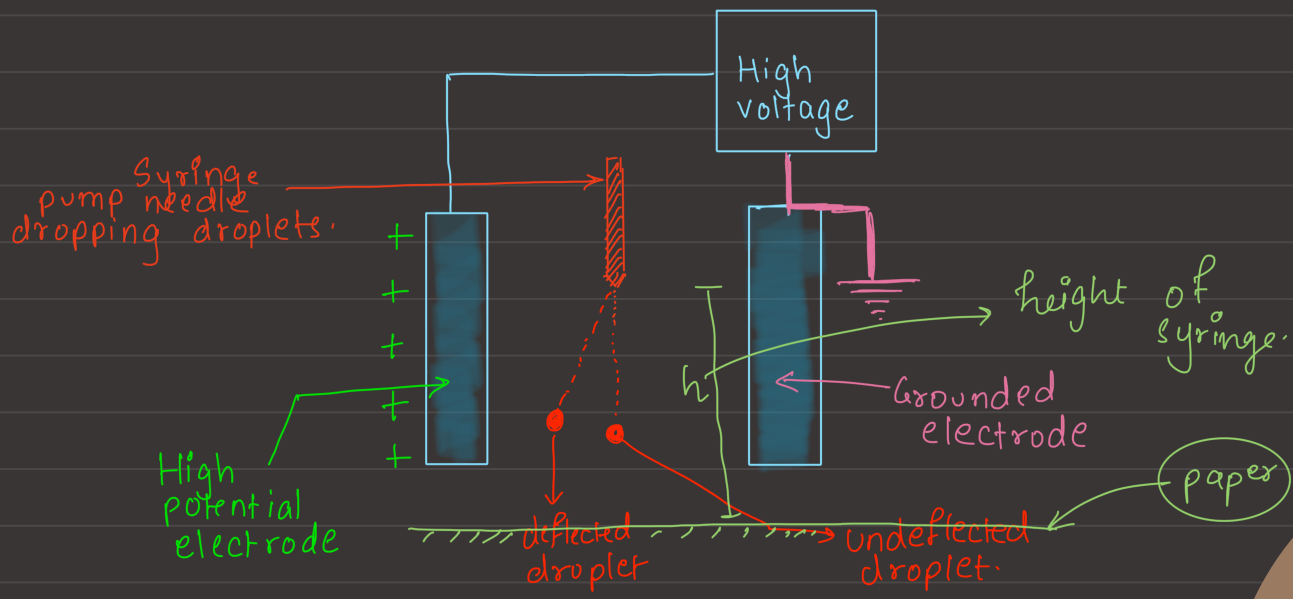
Physics Tutorial Question.

Problem — Drop-on-demand (DOD) inkjet is a type of 3D printing method in which individual droplets are released in succession to print the image. Manipulation of droplets to desired location is crucial for advancing this technology. Out of several options, electrostatic manipulation is one of the most promising option.
Design an experiment and model which will allow such an electrostatic manipulation.

→ Answer:

- Consider the following experimental setup:



- We have to take care of two problems here:
  1] Charging the droplet (glycerol)
  2] Deflecting the droplet in a desired manner.

P.T.O.

(I) Charging the droplet:

→ Let us connect a selectable wire between grounding electrode and the needle.

↳ When direct contact between needle and electrode occurs → ions in droplets get charged because of physical contact.

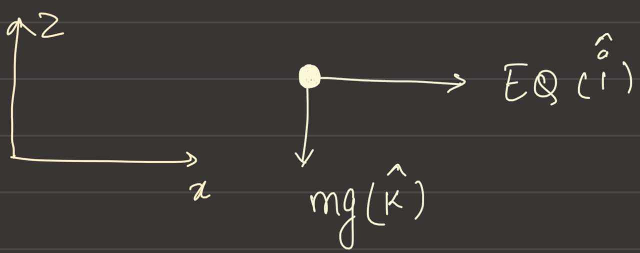
→ The second way of charging the droplets: once the droplet is released, we let the ionised air between high potential electrodes charge the droplets.

* In such a setup, it is easy to change the source potential; and hence electric field between electrodes. This allows the user to determine the amount of droplet deflection.

(II) Deflecting the droplet in desired manner:

→ In order to achieve highly accurate deflection, the main property we need to know is charge on individual droplet.

→ Consider the following diagram showing forces on the released droplet.



→ These give the following differential equations:

In z directional:

$$\cancel{m}\frac{d^2z}{dt^2} = -\cancel{m}g \Rightarrow \boxed{\frac{d^2z}{dt^2} = -g}$$

$$m\frac{d^2x}{dt^2} = EQ \Rightarrow \boxed{\frac{d^2x}{dt^2} = \frac{EQ}{m}}$$

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→ Let time of droplet release be $t=0$

∴ We get boundary conditions that $V_{initial}=0$

$$\therefore \boxed{\frac{dz}{dt}=0\ ,\ \frac{dx}{dt}=0\ \ldots\ \text{at } t=0,\ x=0,\ z=h} \quad \text{— (2)}$$

h = ht of syringe

→ From one and two, we get the following,

$$\boxed{z=\frac{-gt^2}{2}+h\ ,\quad x=\frac{EQt^2}{2m}} \quad \text{— (3)}$$

→ The paper on which droplets collide is located at plane $z=0$ (x-y plane)

∴ time of impact can be found as:

$$0=\frac{-gt^2}{2}+h \Rightarrow \boxed{t=\sqrt{\frac{2h}{g}}} \quad \text{— (4)}$$

→ Substituting this t in $x=\frac{EQt^2}{2m}$, we get the x-co-ordinate of impact

$$\boxed{x_0=\frac{QEh}{mg}} \quad \text{— (5)}$$

→ • We can measure x_0 using high speed cameras and standardise m by using industrial droplet generators (eg. Nordson EFD)

• We know h and E (parameters set before experiment)

• Hence, we can succesfully calculate charge acquired by the droplet as

$$\boxed{Q=\frac{mgx_0}{Eh}} \longrightarrow (6)$$

• formula can be further adjusted to avoid computation of E.

We know that $\int E\cdot dl = V$

Here, $\int dl = L$ = distance bw. electrodes

and E is constant

$\therefore EL=V$

$\therefore E = \frac{V}{L}$

Now, put this in eq^n (6),

$$\boxed{Q = \frac{mgLx_0}{Vv_h}} \implies \boxed{Q \propto \frac{1}{V}}$$

→ In principle, we will know the charge Q acquired by a droplet for a particular setup. And we can vary potential to reach desired deflection.