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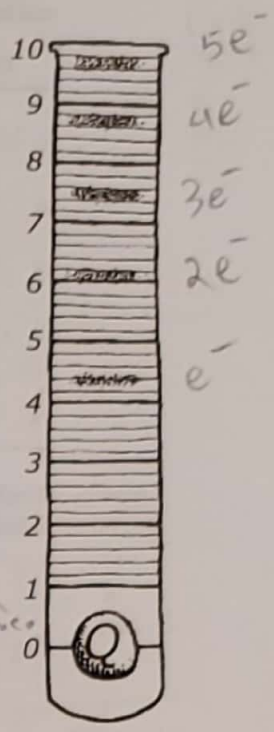
Scenario

A scientist studying pollen collects many identical pollen grains of mass m. The scientist subjects the grains to a process that strips one or more electrons from each grain and then injects the grains into a vertical evacuated tube. At the bottom of the tube is a sphere carrying a charge $Q = 1\ \mu C$. The grains in the tube, subject only to the forces of Earth's gravitational field and the charge Q, group together when they come to equilibrium as shown in the diagram to the right. The numbers on the diagram represent millimeters of distance.



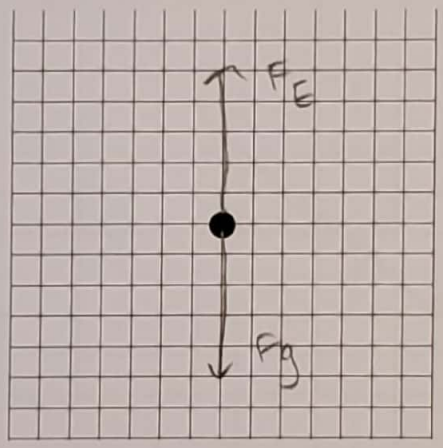
Data Analysis

PART A: Briefly explain why the grains group together rather than being distributed at all points in the tube.

The grains group together since the distance from the sphere is dependent on the charge of the pollen. Therefore, grains of equal charge will be suspended from the same distance from the sphere. Each electron is also taken at a time.

quantized charge = x (charge on e^-)

PART B: Draw a diagram of the forces exerted on a single grain and use the diagram to write an equation that expresses the exerted forces in terms of m, Q, y (the vertical height of the pollen grain), and q (the charge on that grain), plus any other physical constants needed.



$\Sigma F_y = ma_y$

$F_E - F_g = 0$

$F_E = F_g$

$\frac{kQq}{y^2} = mg$

Write the net force equation in the y-direction

The two forces acting are F_E and F_g.

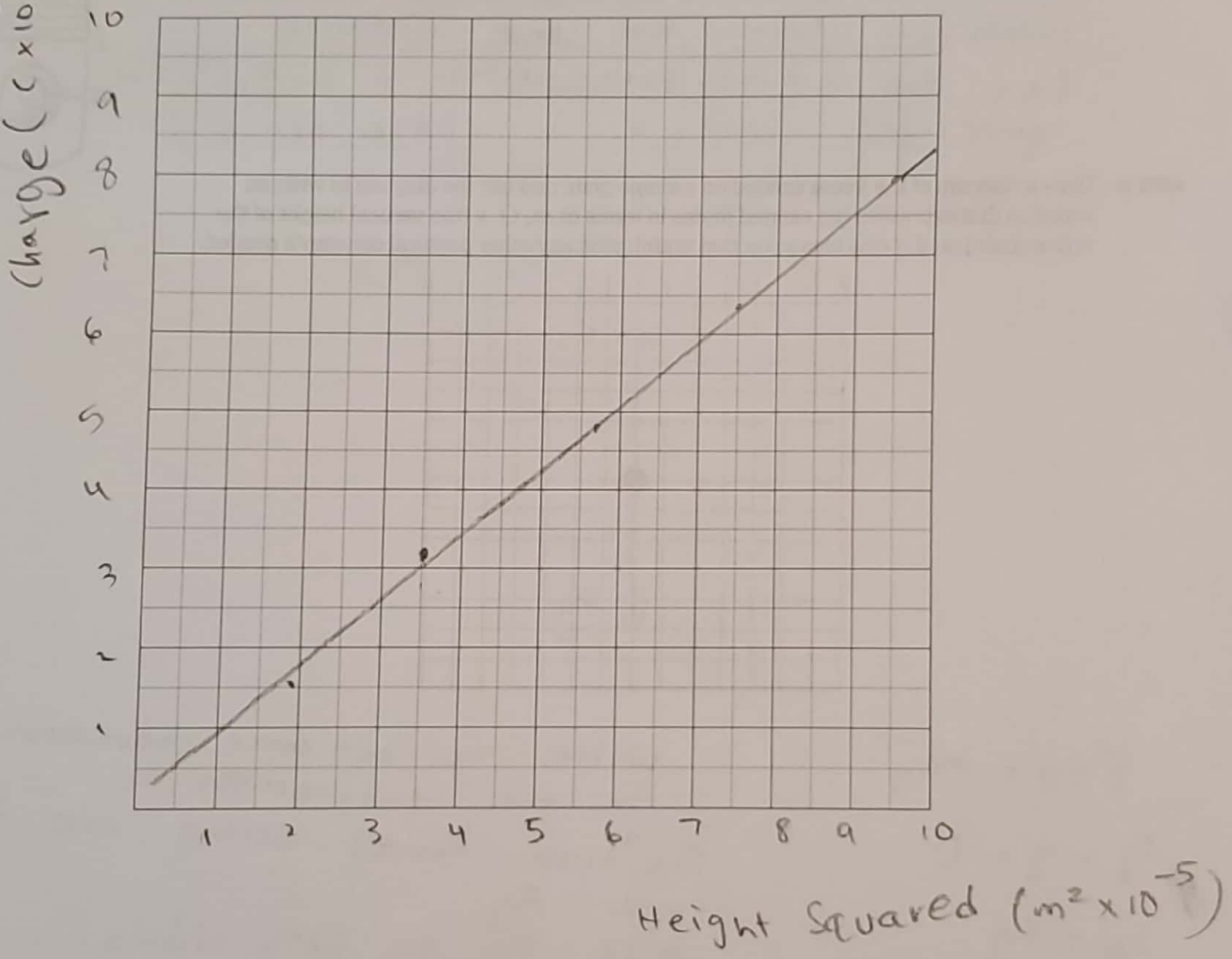
Add F_g to both sides

Plug in F_E as $\frac{kQq}{y^2}$ and F_g as mg.

PART C: Using the diagram given in the scenario, fill in the table below with the charge q on a single grain and height y of a single grain. Note that you are asked to calculate the quantity y^2.

Charge q (C)	Height y (m)	y^2 (m^2)
1.6×10^{-19}	4.4×10^{-3}	1.89×10^{-5}
3.2×10^{-19}	6.10×10^{-3}	3.72×10^{-5}
4.8×10^{-19}	7.50×10^{-3}	5.63×10^{-5}
6.4×10^{-19}	8.70×10^{-3}	7.57×10^{-5}
8.0×10^{-19}	9.70×10^{-3}	9.41×10^{-5}

PART D: Graph q vs. y^2 from your data table on the grid below. Draw a best-fit line. Use the slope of the best-fit line (not an average or a single data point) to calculate the mass m of a pollen grain.



PART E: Explain how you used the equation from Part B to determine the meaning of the slope of the graph by giving the relationship between the mass of a pollen grain and the slope of the line above.

$mg = \frac{kQq}{y^2}$ ← equation from part B

$\frac{q}{y^2} = \frac{mg}{kQ}$ ← rearrange equation

slope from graph = $\frac{3.2 \times 10^{-19} (\text{C}) - 1.6 \times 10^{-19} (\text{C})}{3.72 \times 10^{-5}\ \text{m}^2 - 1.89 \times 10^{-5}\ \text{m}^2}$

$= 8.743169399 \times 10^{-15} = \frac{mg}{kQ}$ ← set slope to rearranged equation

$8.743 \times 10^{-15} = \frac{m \cdot 9.8}{9.0 \times 10^{9} \cdot (1 \times 10^{-6})}$

$\therefore \boxed{m = 8.029 \times 10^{-12}\ \text{kg}}$