

# *Electricity & Magnetism*

## *Lecture 4+: More Gauss' Law*

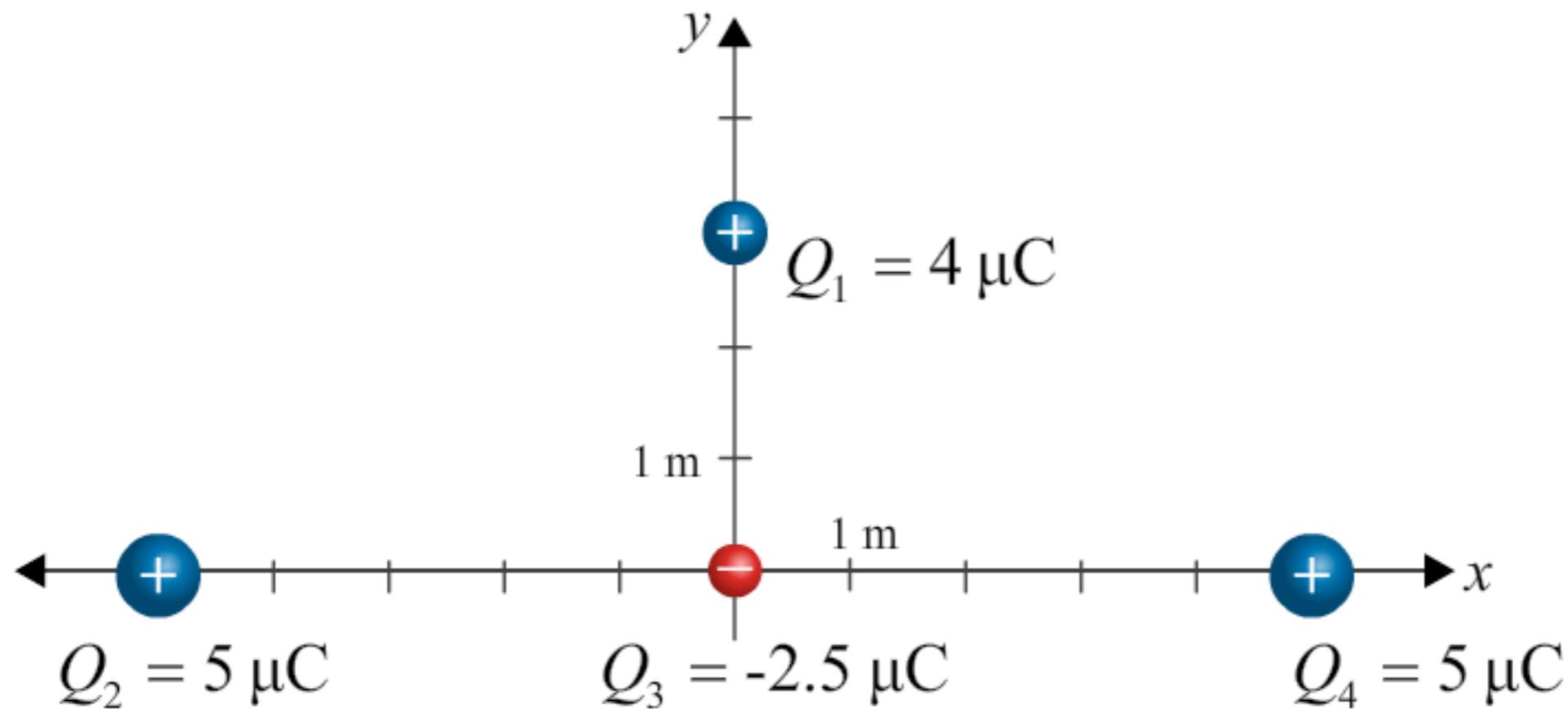
### Today's Topics:

Practise Problems

Theoretical Exercises in Activity Guide

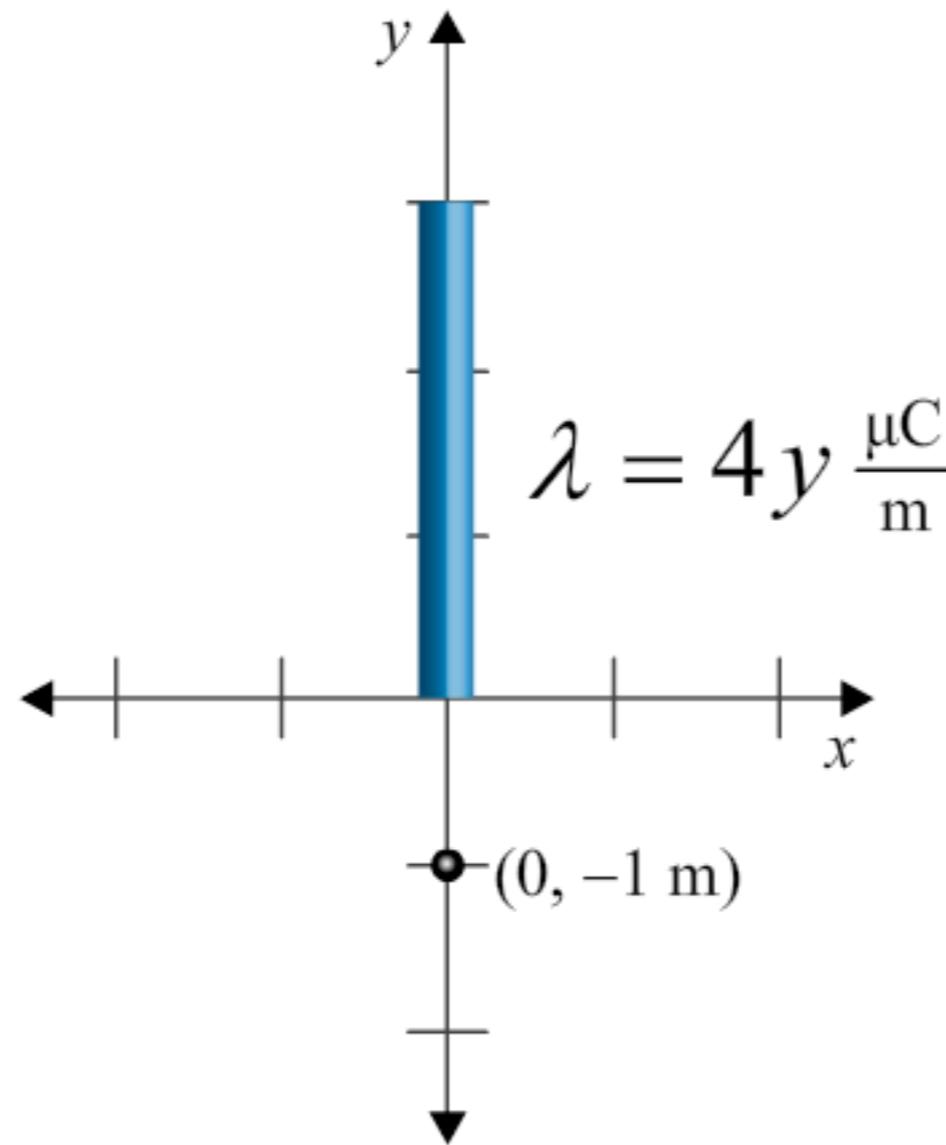
# Coulomb's Law Problem

**Problem:** There are four charged particles at fixed positions in a coordinate system as shown. Determine the net force on the particle 1, located on the positive  $y$ -axis.



# Electric Field Problem

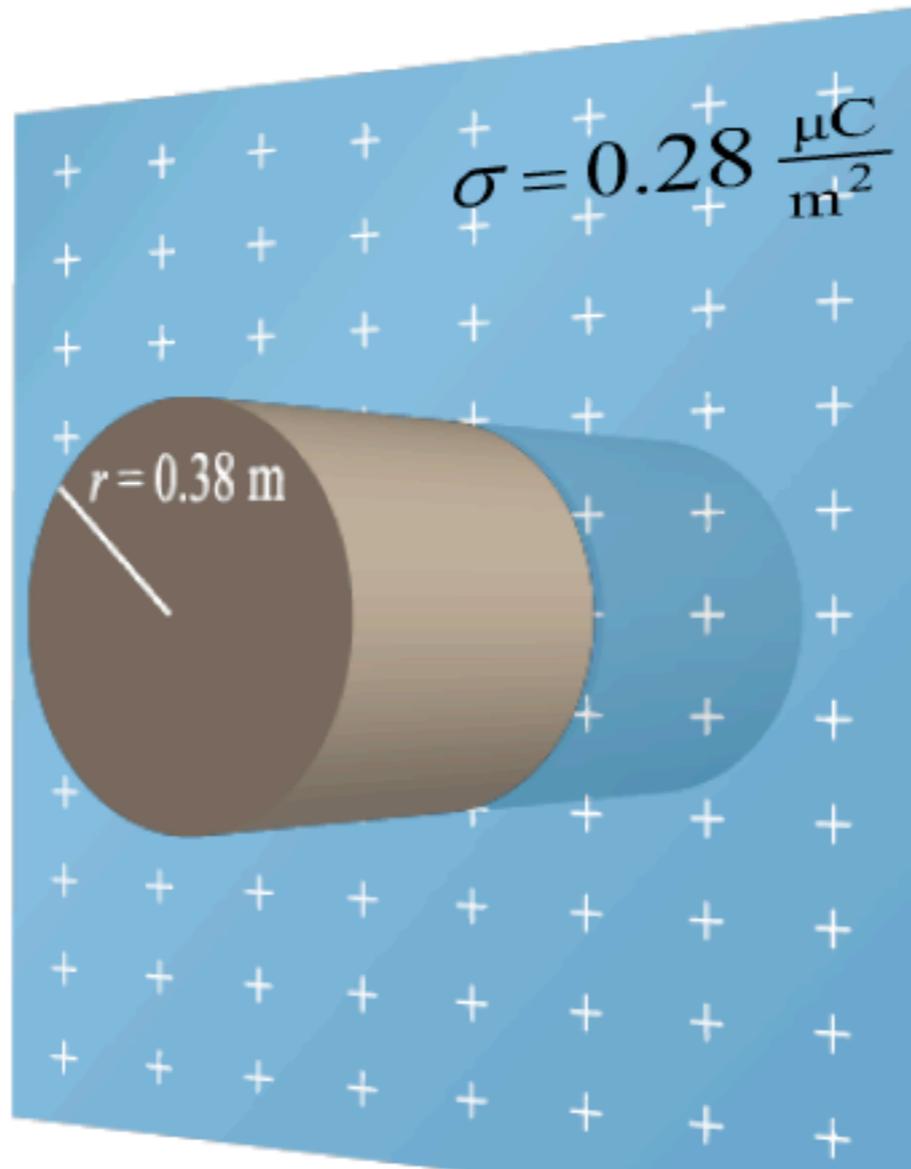
**Problem:** In this example we have a finite, continuous line of charged particles with a non-uniform charge distribution. The charge density is linear with respect to the  $y$ -coordinate. Determine the electric field at the point  $(0, -1 \text{ m})$ .



[Worked Example](#)

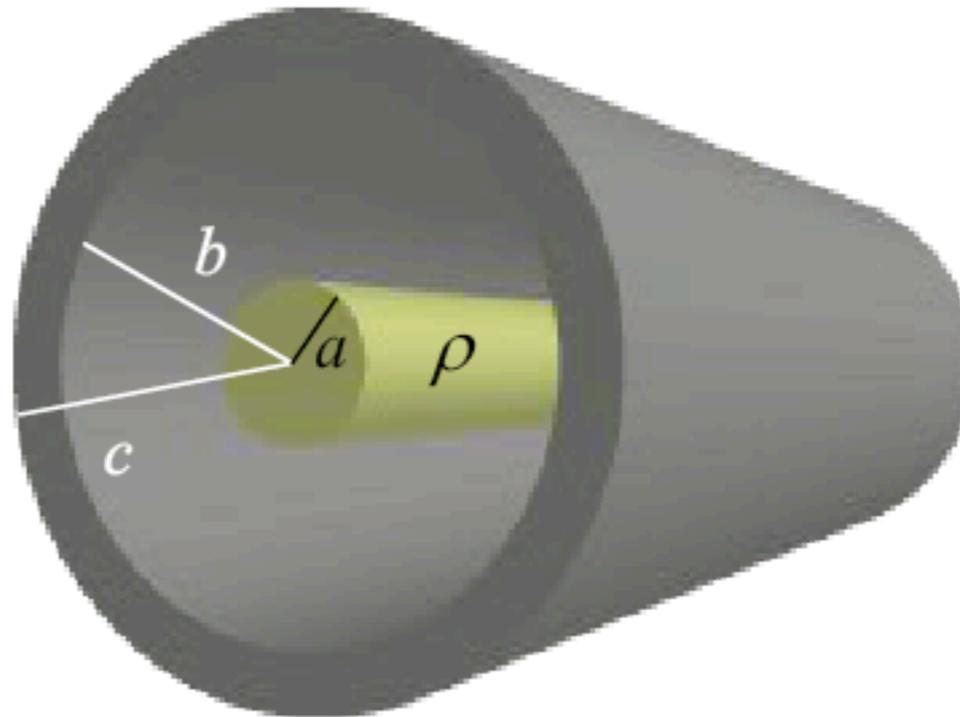
# Electric Flux Problem

**Problem:** A large conducting plate has a uniform charge density of  $\sigma = 0.28 \mu\text{C}/\text{m}^2$ . Consider a cylindrical container with radius  $r = 0.38 \text{ m}$ , and length  $L = 1.4 \text{ m}$  perpendicular to and bisected by the plane. Calculate the electric flux through the barrel and each end of the cylinder.

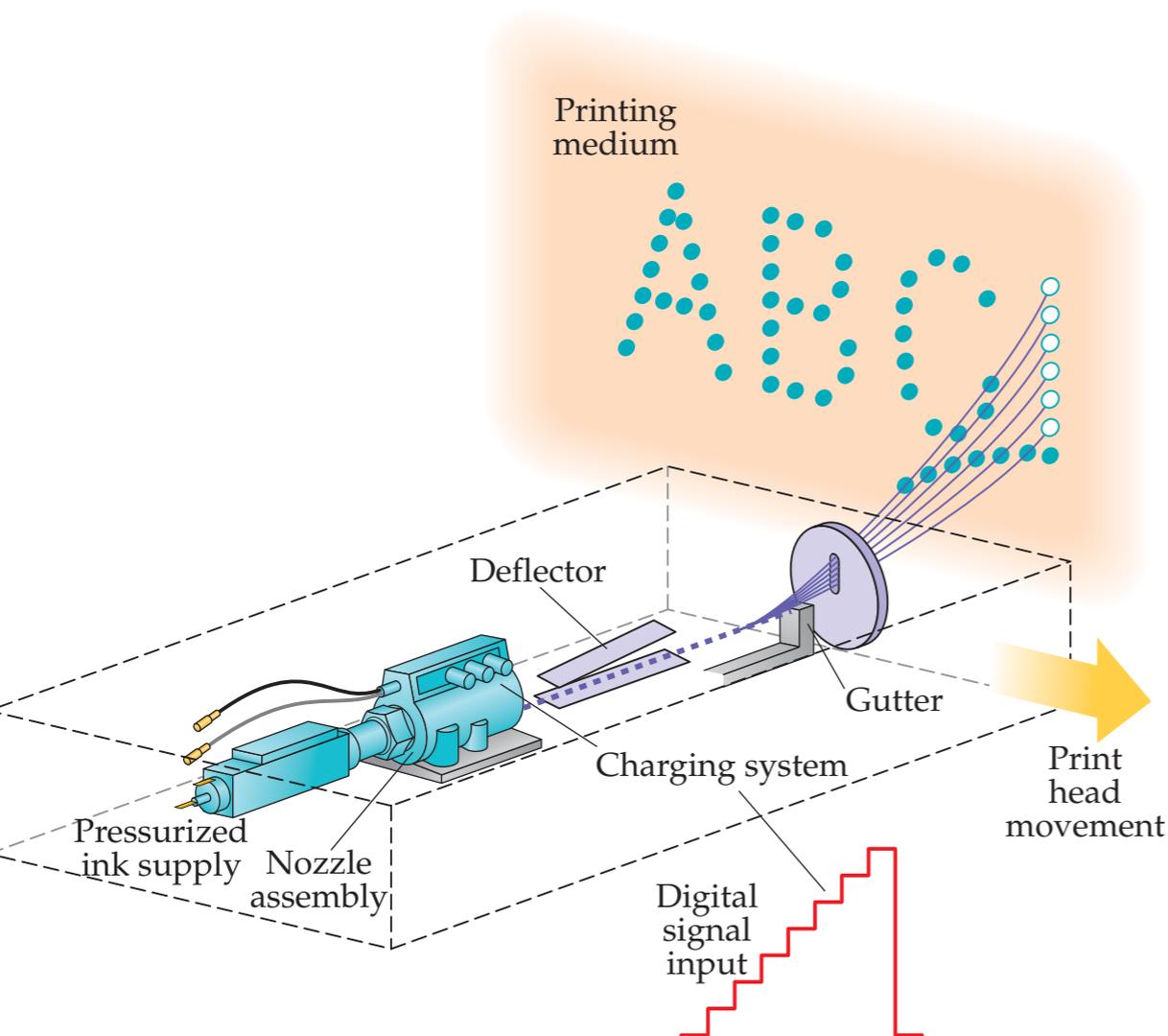


# Gauss' Law Problem

**Problem:** An infinitely long, cylindrical insulator of radius  $a$  has a uniform volume-charge density,  $\rho$ . The insulator is surrounded by an uncharged, concentric, conducting shell of inner radius  $b$  and outer radius  $c$ . Determine the magnitude of the electric field as a function of  $r$ , the distance from the axis of the cylinder.



# The Electric Field in an Ink-Jet Printer



The ink exits the nozzle in discrete droplets. Any droplet destined to form a dot on the image is given a charge. The deflector consists of a pair of oppositely charged plates. The greater the charge a drop receives, the higher the drop is deflected as it passes between the deflector plates.

The  $40.0\text{-}\mu\text{m}$ -diameter ink drops have an initial velocity of  $40.0\text{ m/s}$ , and that a drop that has a  $2.00\text{-nC}$  charge is deflected upward a distance of  $3.00\text{ mm}$  as the drop travels through the  $1.00\text{-cm}$ -long region between the plates.

Find the magnitude of the electric field.

# The Electric Field in an Ink-Jet Printer 2

**PICTURE** The electric field  $\vec{E}$  exerts a constant electric force  $\vec{F}$  on the drop as it passes between the two plates, where  $\vec{F} = q\vec{E}$ . We are looking for  $E$ . We can get the force  $\vec{F}$  by determining the mass and acceleration  $\vec{F} = m\vec{a}$ . The acceleration can be found from kinematics and mass can be found using the radius. Assume the density  $\rho$  of ink is  $1000 \text{ kg/m}^3$  (the same as the density of water).

# The Electric Field in an Ink-Jet Printer 3

## SOLVE

1. The electric field strength equals the force to charge ratio:

$$E = \frac{F}{q}$$

2. The force, which is in the  $+y$  direction (upward), equals the mass multiplied by the acceleration:

$$F = ma_y$$

3. The vertical displacement is obtained using a constant-acceleration kinematic formula with  $v_{0y} = 0$ :

$$\Delta y = v_{0y}t + \frac{1}{2}a_y t^2 = 0 + \frac{1}{2}a_y t^2$$

4. The time is how long it takes for the drop to travel the  $\Delta x = 1.00$  cm at  $v_0 = 40.0$  m/s:

$$\Delta x = v_{0x}t = v_0 t \quad \text{so} \quad t = \Delta x/v_0$$

5. Solving for  $a_y$  gives:

$$a_y = \frac{2\Delta y}{t^2} = \frac{2\Delta y}{(\Delta x/v_0)^2} = \frac{2v_0^2\Delta y}{(\Delta x)^2}$$

6. The mass equals the density multiplied by the volume:

$$m = \rho V = \rho \frac{4}{3}\pi r^3$$

7. Solve for  $E$ :

$$E = \frac{F}{q} = \frac{ma}{q} = \frac{\rho \frac{4}{3}\pi r^3}{q} \frac{2v_0^2\Delta y}{(\Delta x)^2} = \frac{8\pi}{3} \frac{\rho r^3 v_0^2 \Delta y}{q(\Delta x)^2}$$
$$= \frac{8\pi}{3} \frac{(1000 \text{ kg/m}^3)(20.0 \times 10^{-6} \text{ m})^3(40.0 \text{ m/s})^2(3.00 \times 10^{-3} \text{ m})}{(2.00 \times 10^{-9} \text{ C})(0.0100 \text{ m})^2}$$

$$= 1.61 \text{ kN/C}$$