# Gauss's Law (II)

- Examples: charged spherical shell, infinite plane, long straight wire

Text section 24.3

*Practice problems:*
*Chapter 24,*
*Conceptual Question 4*
*Problems 26, 29, 30, 33, 35*

*Read section 24.3 carefully, including field of a line or cylinder.*

# Gauss's Law

*For a <u>closed</u> surface S:*

$$\text{Net outward flux through S} = \frac{\text{net charge enclosed}}{\varepsilon_o}$$

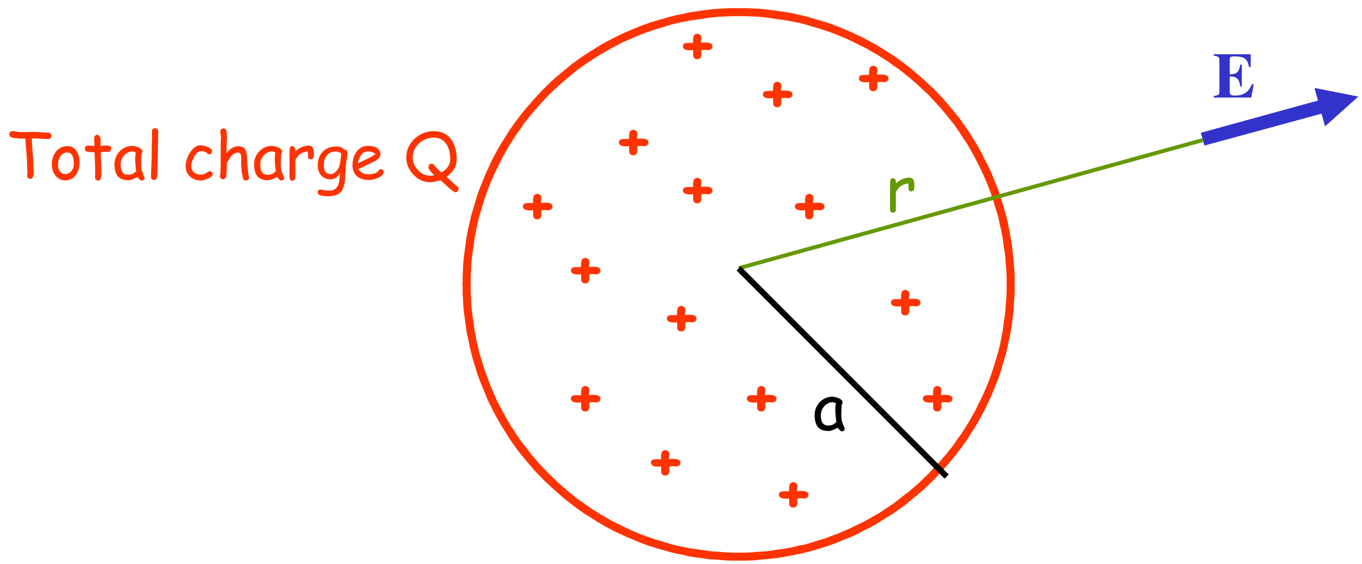
# Calculating E  for symmetric charge distributions

1) Use symmetry to sketch the behaviour of **E** (*possible only for very symmetric distributions*)
2) Pick an *imaginary* "gaussian surface" S
3) Calculate the flux through S, in terms of an unknown |**E**|
4) Calculate the charge enclosed by S from geometry
5) Relate 3) and 4) by Gauss's Law, solve for |**E**|

# Example: **Uniformly Charged Sphere**

(uniform *volume density* of charge)

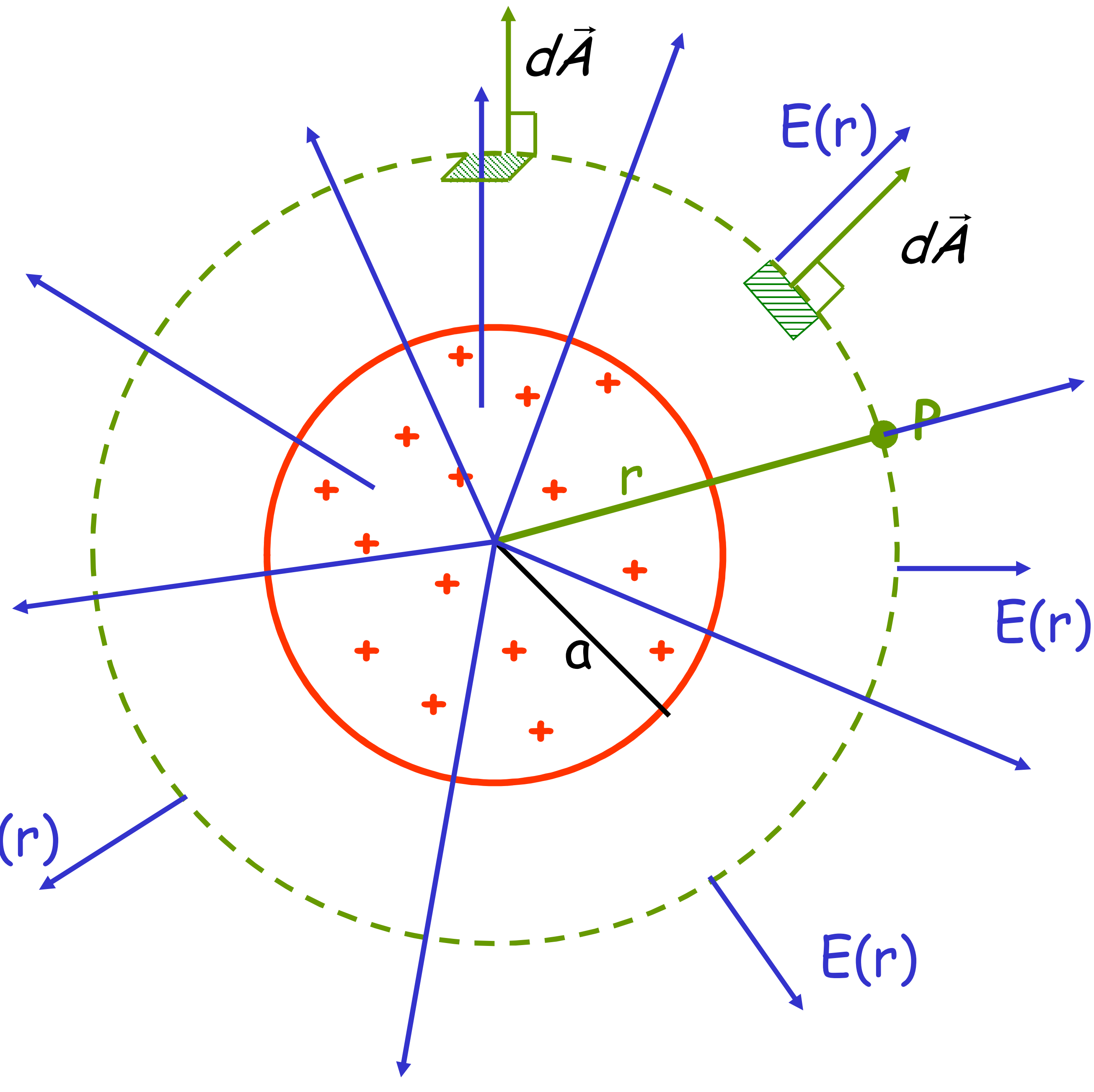
$$\rho = \frac{\text{charge}}{\text{unit volume}} = \text{constant}\ (r < a)$$



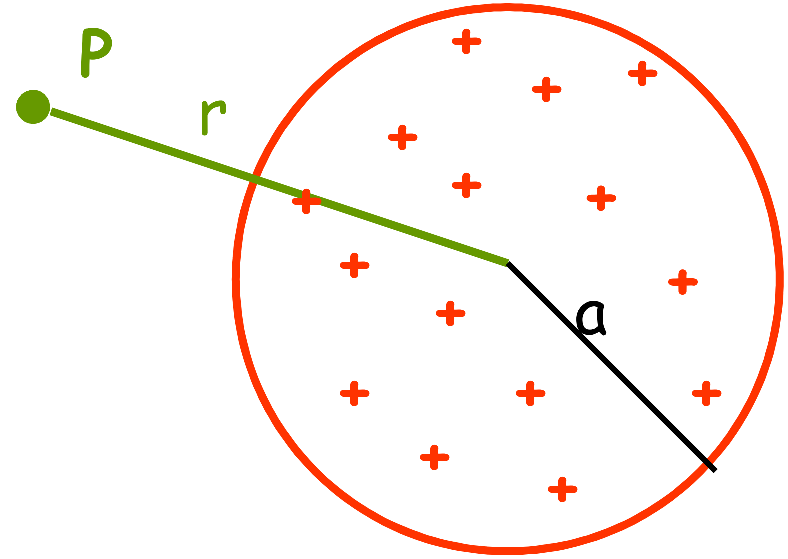

Find $\mathbf{E}$ for: i) r > a

and ii) r < a

i) r > a



i) r > a



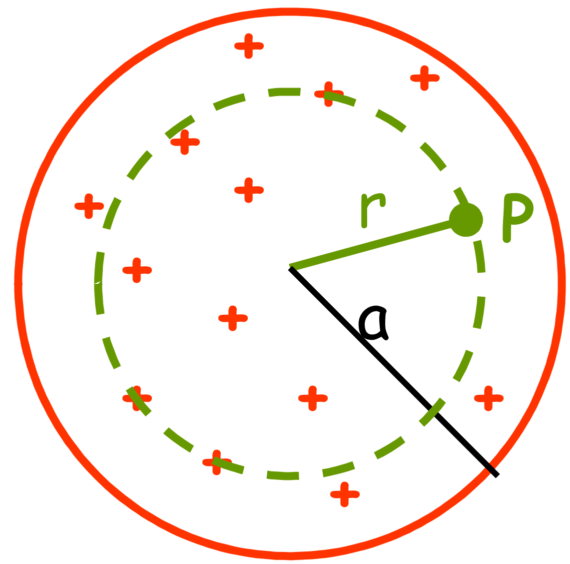

$$E = \frac{Q_{Total}}{4\pi\varepsilon_o r^2}$$

ii) For $r < a$

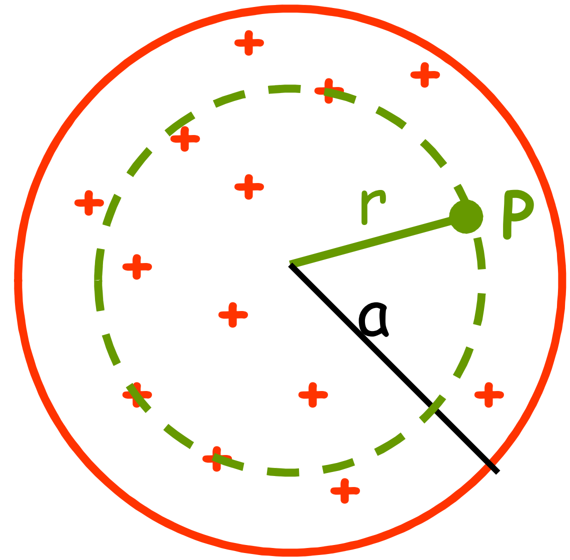
## Quiz

*For $r < a$, the charge enclosed within the dashed green gaussian sphere is proportional to*

A) $r$
B) $r^2$
C) $r^3$
D) is independent of $r$



ii) $r < a$

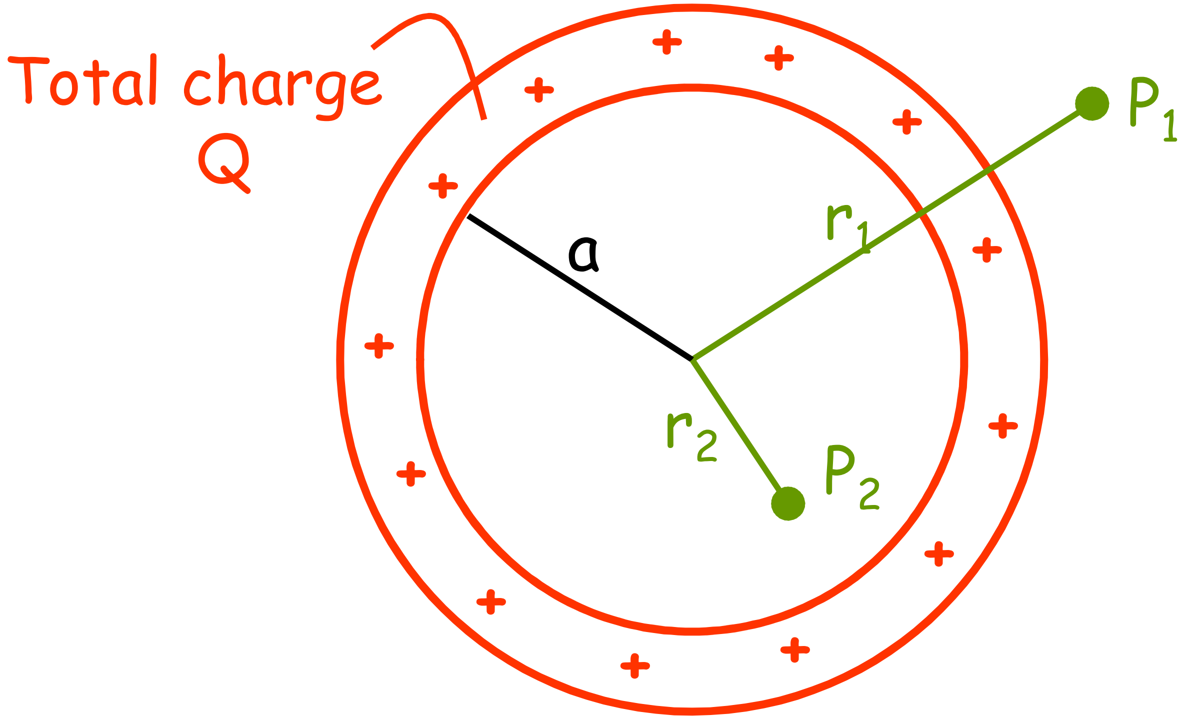


For any **spherically – symmetric** charge:

$$E(r) = \frac{Q(r)}{4\pi\varepsilon_o r^2}$$

Where Q(r ) = charge enclosed within an (imaginary) sphere of radius r

# Example: Hollow Spherical Shell




Outside: $(r_1 > a)$:

Inside: $(r_2 < a)$:

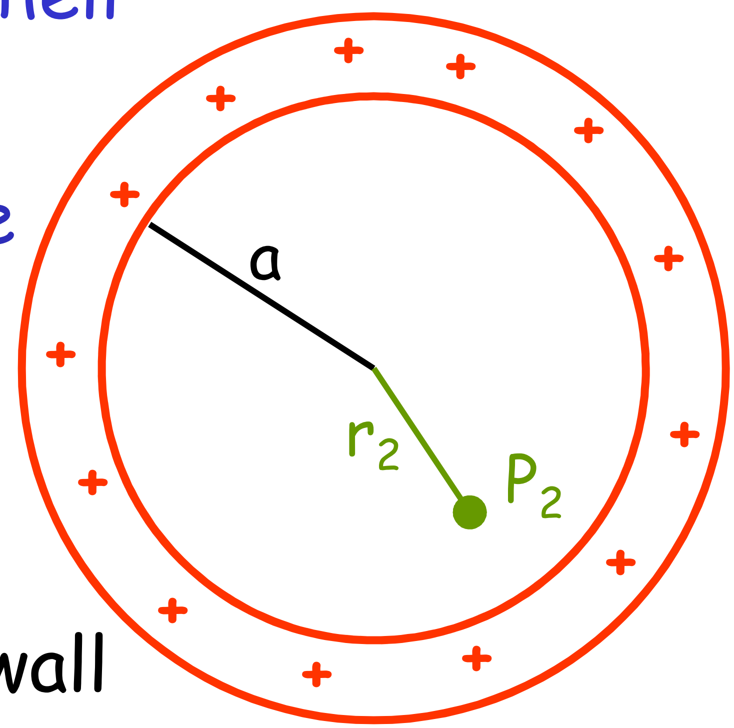
# Quiz: Hollow Spherical Shell

*Inside* the shell, we expect the field to be:

A) zero everywhere inside

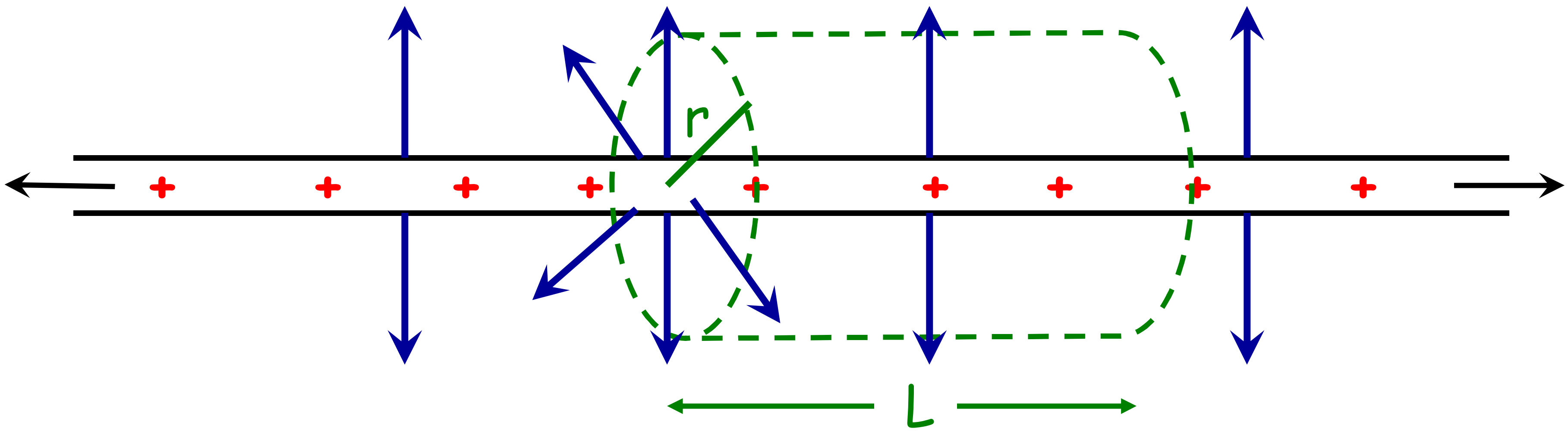
B) not zero at point $P_2$, and pointing **outwards** towards the wall

C) not zero at point $P_2$, and pointing **inwards** towards the centre



# Infinite Line Charge (Long Wire)

$$\lambda = \frac{\text{charge}}{\text{unit length}} = \text{constant}$$



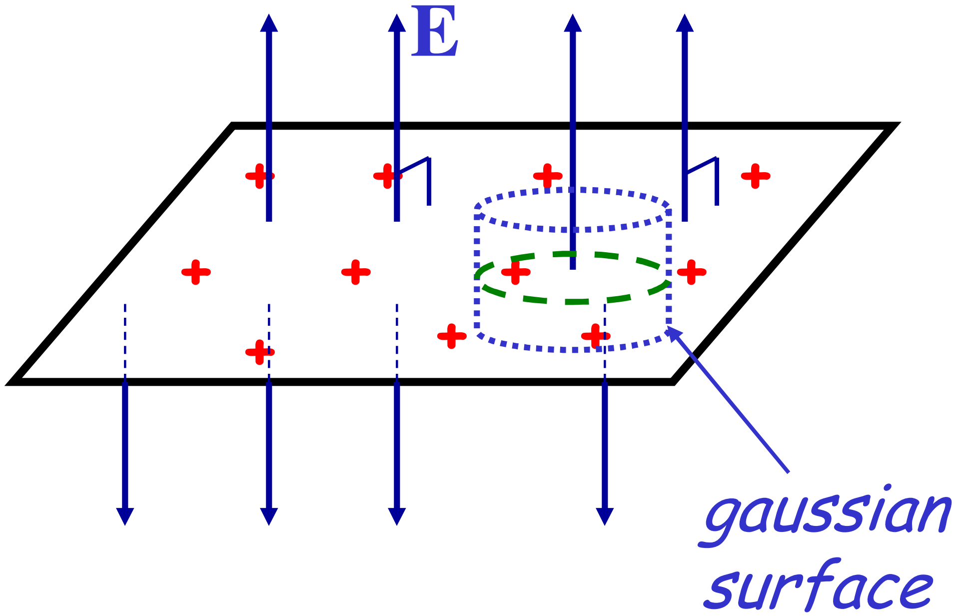

Flux: $0 + 0 + (2\pi r L) \times E(r)$

$Q_{enclosed}$: $\lambda L$

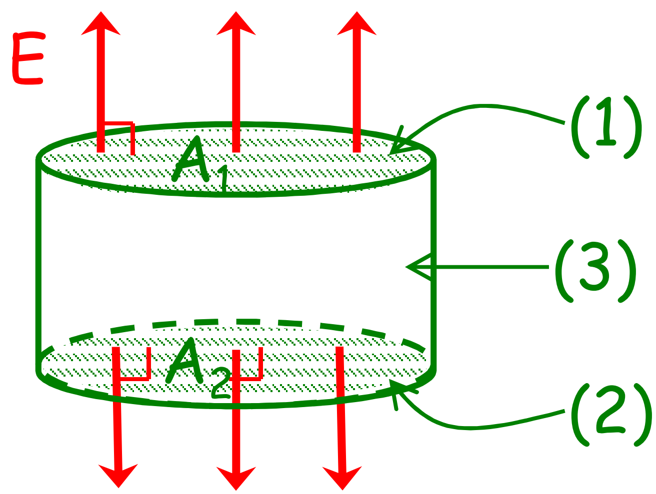
$$\therefore\ (2\pi r L) E(r) = \frac{\lambda L}{\epsilon_o} \quad \Rightarrow \boxed{E = \frac{\lambda}{2\pi r \epsilon_o}} \quad (\propto \frac{1}{r})$$

# Uniformly-Charged Thin Sheet

$$\sigma = \frac{\text{charge}}{\text{unit area}} \quad \text{is uniform}$$



(3) Flux:




$\Phi_1 =$

$\Phi_2 =$

$\Phi_3 =$

$\Phi_{TOTAL} =$

(4) $Q_{enclosed}$ =

# Quiz

*The electric field 10 cm above an infinite, uniformly-charged plane is 100 N/C. At a point 20 cm above the plane, the field would be*

A) zero
B) 100 N/C
C) 50 N/C
D) 25 N/C