Lecture 13 outline:

- Behavior of conductors
  - Charge distribution on “lumpy” conductors (for Isaac Edelman)
- Definition of Capacitance
  - General definition of capacitance (for Riley Wayne)
- Capacitance of parallel plates
- Coaxial capacitors
- Potential of a Disk

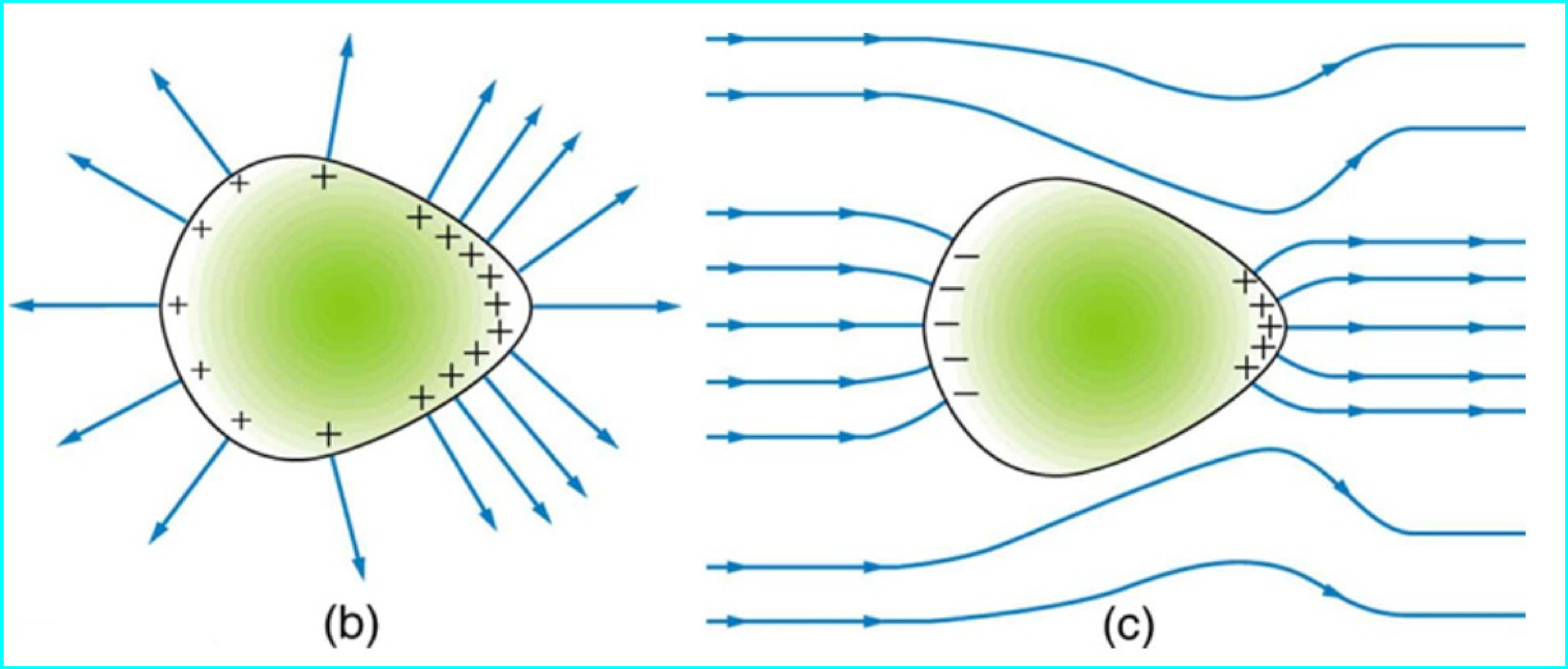
WHY DOES σ VARY WITH CURVATURE?

The picture below is an exaggeration.

Charge only varies as the 4th root of curvature

(and even that is an approximation for ellipsoids

$$\sigma \sim K^{1/4}$$



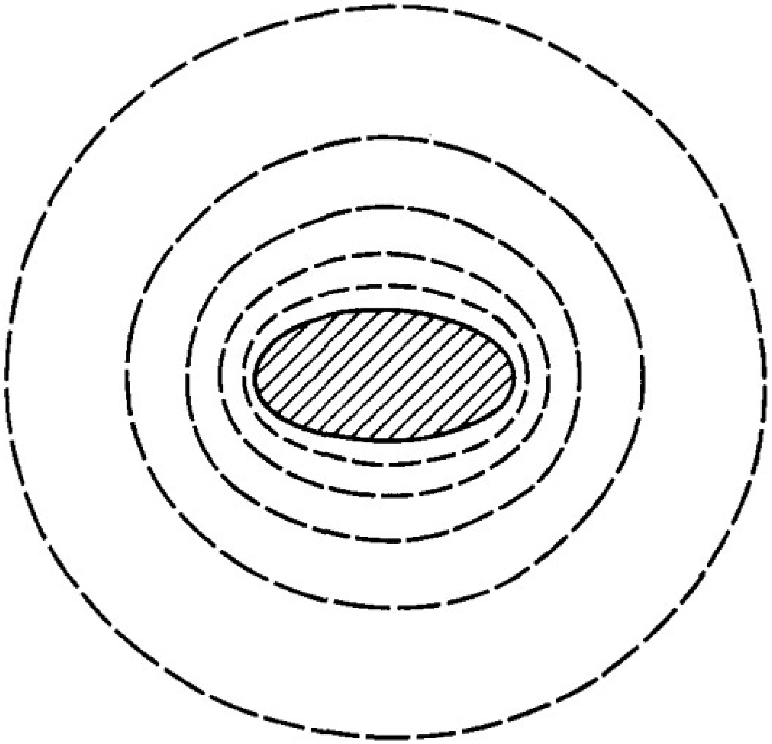


Fig. 1. Proof that |E| is always greatest where the curvature is greatest. The equipotentials (dashed lines) are most closely spaced, and hence the **E** strength is greatest, where the curvature is greatest.

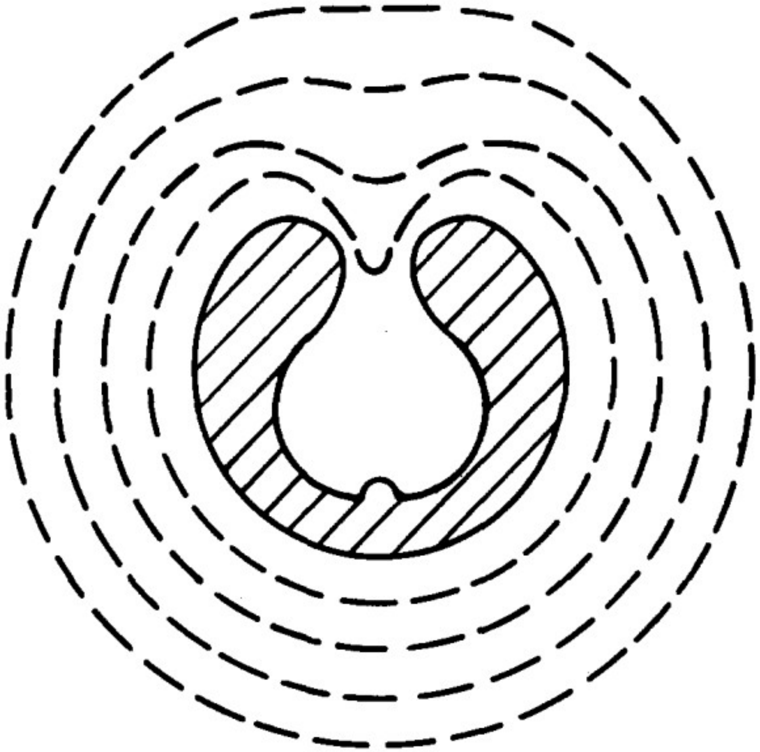
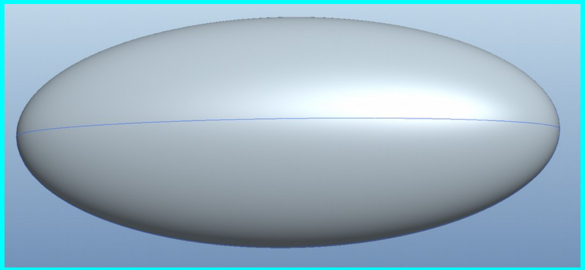
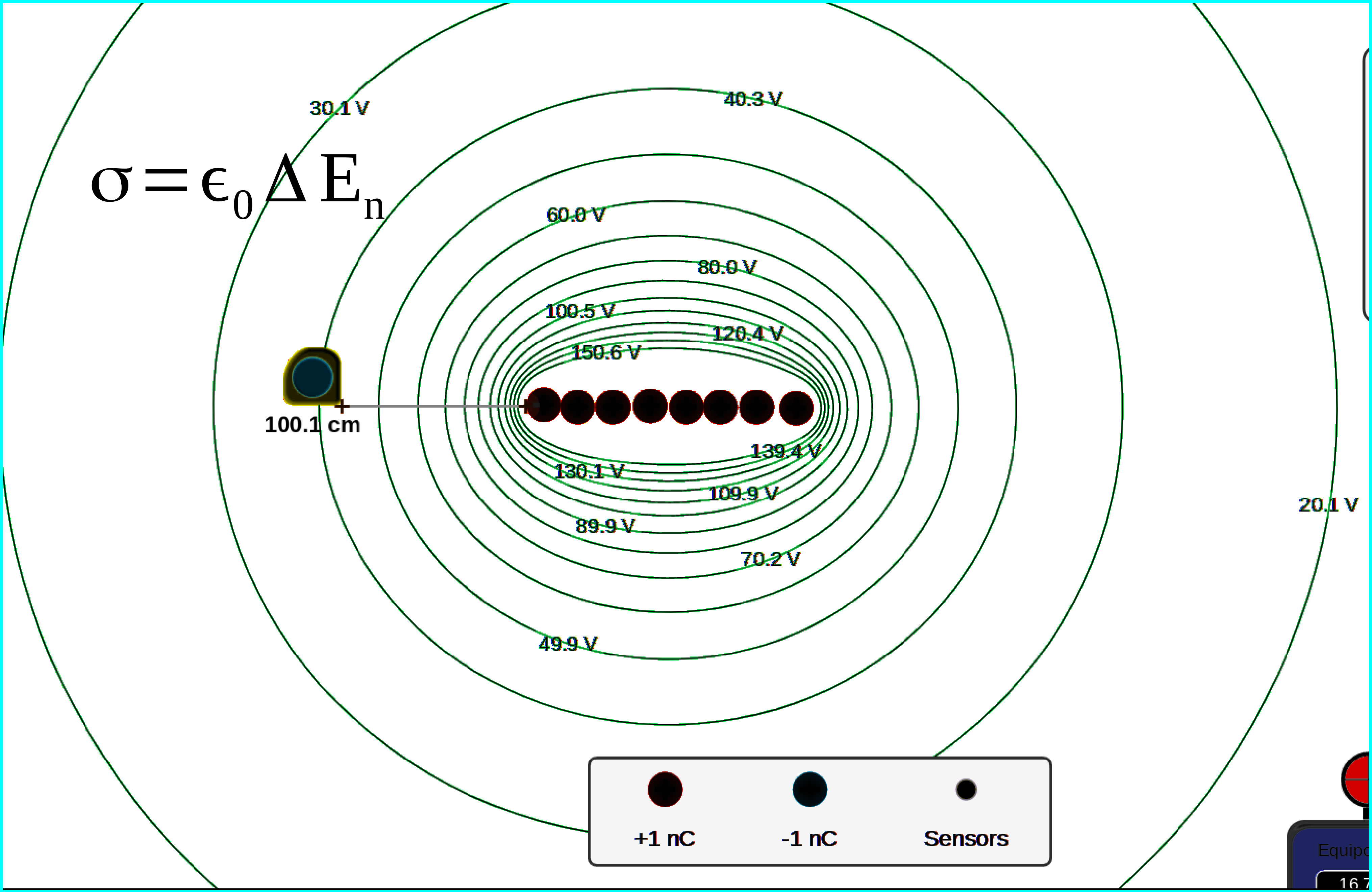


Fig. 2. Proof that |**E**| is not always greatest where the curvature is greatest. (Figure 2, like Fig. 1, represents a cross section of a solid conductor formed by rotating the figure about the vertical symmetry axis.) The curvature is greatest at the bottom of the hollow, on the small hemispherical pimple, but the **E** field there can be made arbitrarily small by narrowing the gap at the top.



Any equipotential could be a metal surface.

$$\sigma = \epsilon_0 \Delta E_n$$



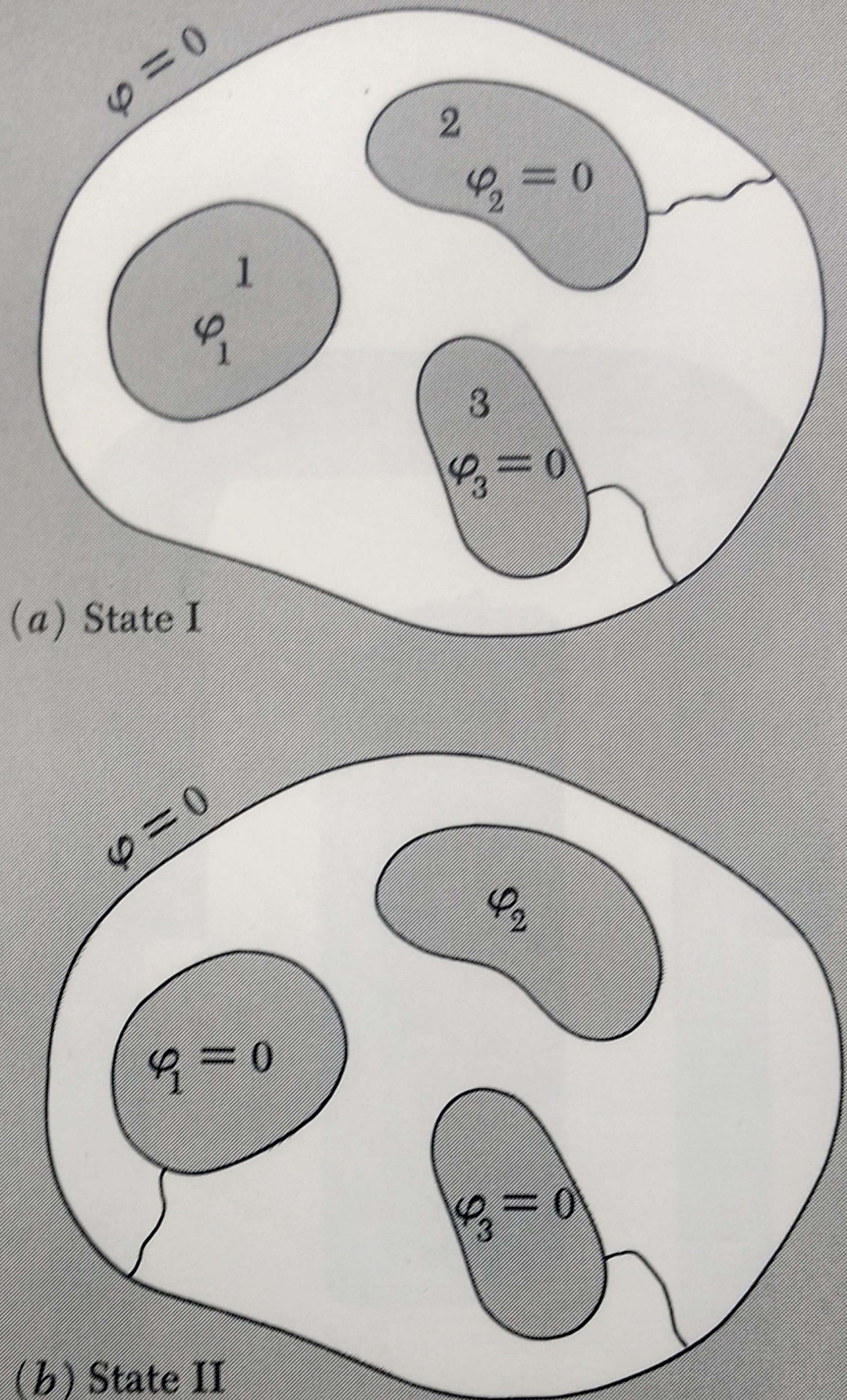
CAPACITANCE

Arbitrary conductors charged equal and opposite

Calculate potential: $C = Q / V$

It is simpler when one conductor surrounds the other,

Gauss's law forces the charges to be equal and opposite.



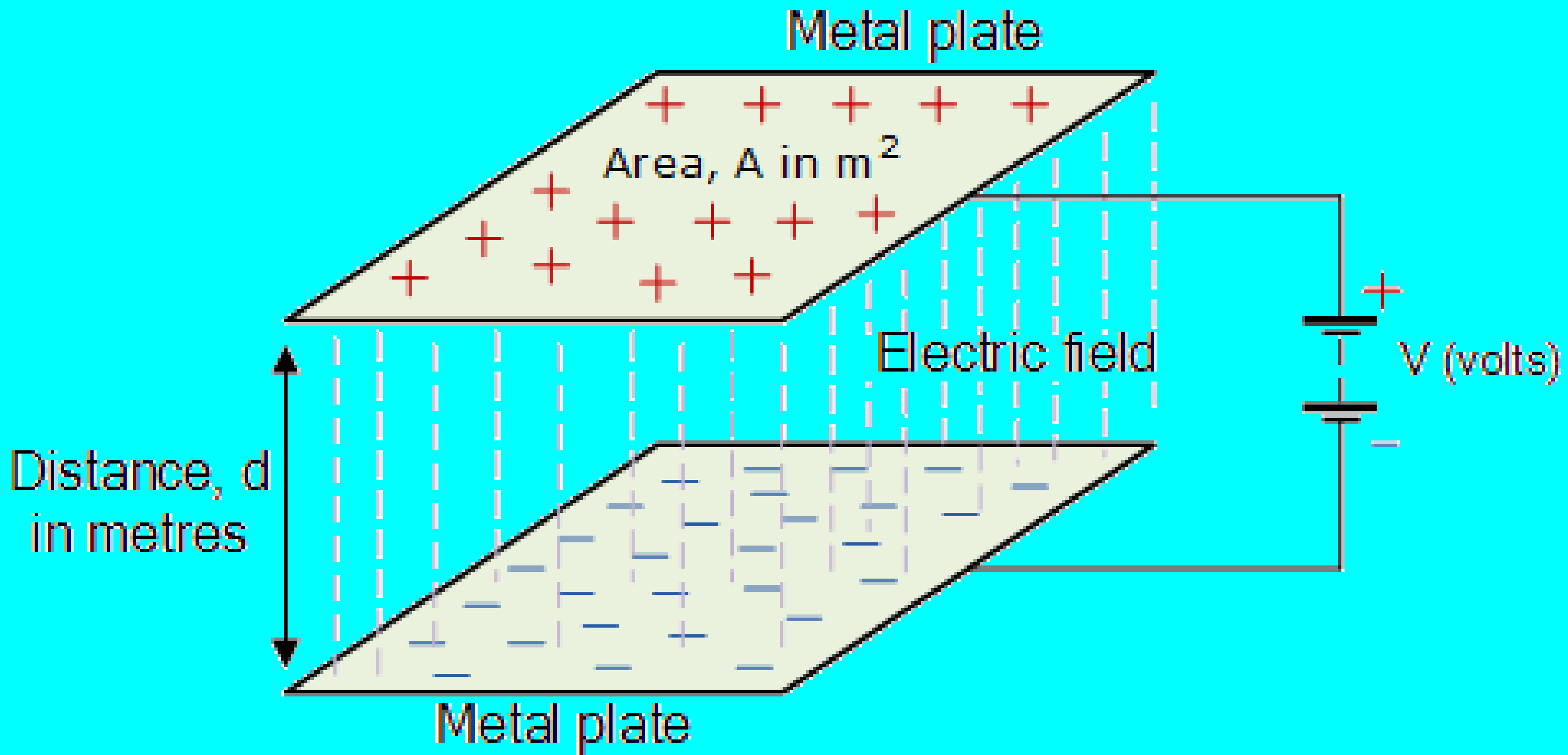
It is NOT required to just have two conductors, or for them to all have the same charges.

See Purcell and Morin 3rd edition, p 147.

But you can calculate or measure the capacitance for any pair of conductors.

Parallel Plate Capacitor

Parallel Plate Capacitor



A square plate has a total charge Q=18 nC and has sides of length 3 meters. Assume the charge is uniformly distributed.

What is the surface charge density σ ?

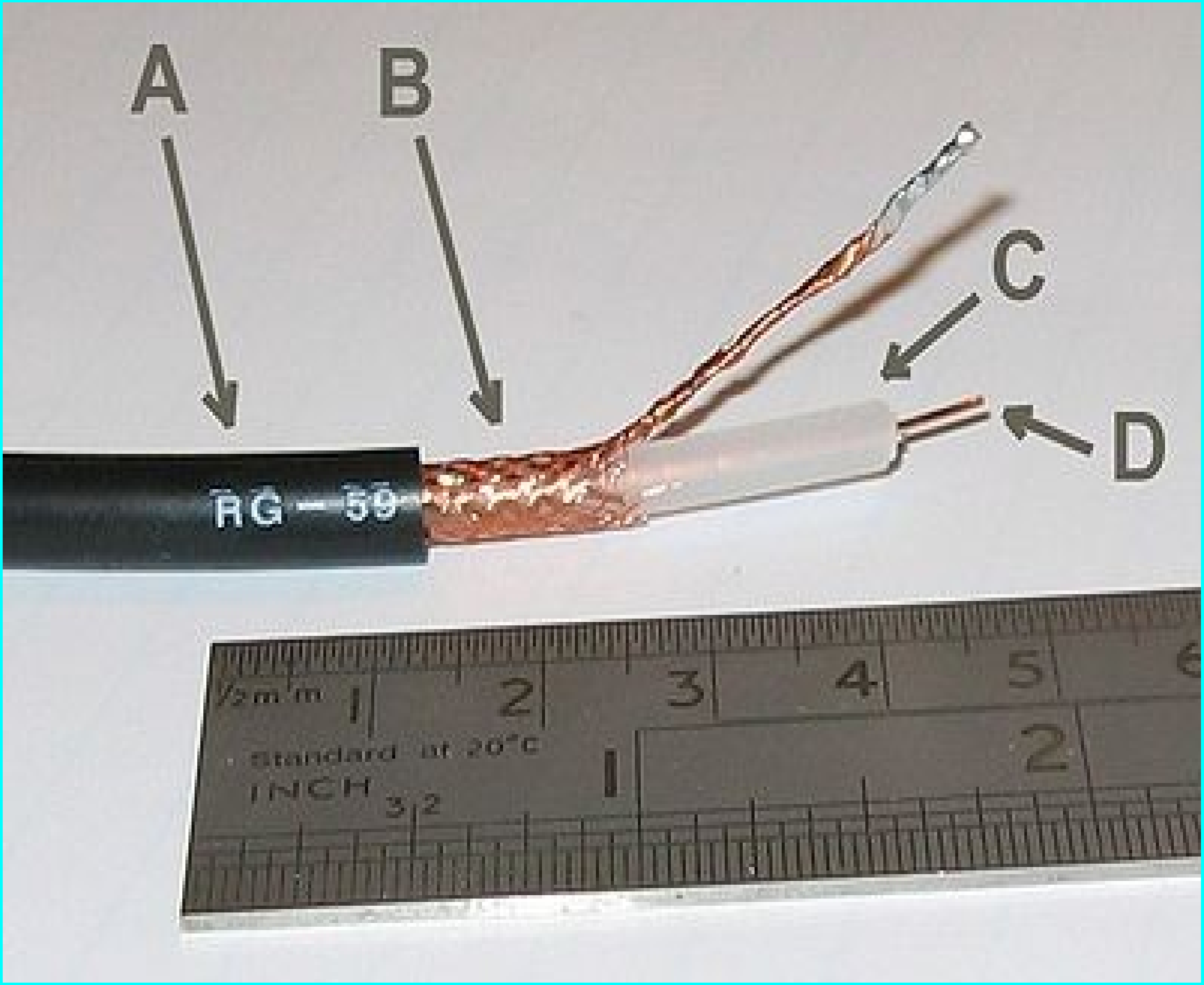
A) $\sigma = 18\, nC/m^2$

B) $\sigma = 6\, nC/m^2$

C) $\sigma = 2\, nC/m^2$

D) $\sigma = 1\, nC/m^2$

E) It depends on which surface the charge is on


A
B
C
D
RG - 59
½m m 1 2 3 4 5 6
Standard at 20°C
INCH 32
1 2

RG 58/U Type

Product Construction:

Conductors:

- Copper per ASTM B-3
- Tinned copper per ASTM B-33

Insulation/Core:

- Solid and foam polyethylene (PE) designs
- Solid and foam fluoropolymer (FEP) design

Shield:

- Tinned copper braid

Jacket:

- Premium PVC compound

Packaging:

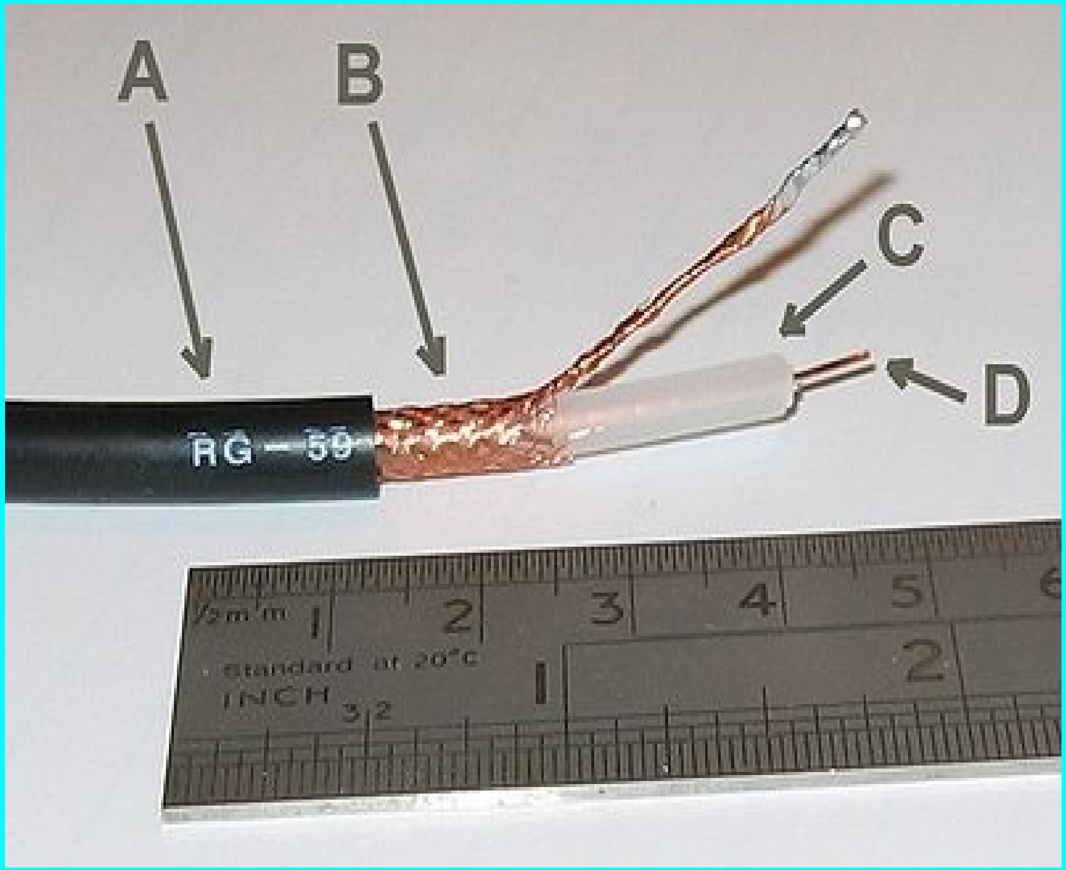
- Please contact Customer Service for packaging and color options

Applications:

- Suitable for RF signal transmission
- Broadcast
- LAN & data transmission
- See Coax Connector Cross Reference, pages 192-199

CATALOG NUMBER	AWG SIZE NOM. DCR	INSULATION MATERIAL		SHIELD COVERAGE NOM SHLD DCR	NOMINAL O.D.		NOMINAL CAPACITANCE		VELOCITY OF PROPAGATION, %	NOMINAL IMPEDANCE, Ω	NOMINAL ATTENUATION	
		INCHES	mm		INCHES	mm	pF/ft	pF/m			MHz	dB/100'
C1117 **RG 58/U Type** 	20 Ga. Solid Bare Copper 10.1 Ω/Mft.	Solid PE		70% Tinned Copper Braid 6.0 Ω/Mft.	Black PVC		28.50	93.51	66	53	1 10 50 100 200 500 1000	0.40 1.20 2.90 4.20 6.00 10.17 16.50
		0.116	2.95		0.195	4.95						
C1155 **RG 58 C/U Type** **MIL-C-17G Type** 	20 Ga. (19/.0071) Tinned Copper 10.8 Ω/Mft.	Solid PE		95% Tinned Copper Braid 4.3 Ω/Mft.	Non-Contaminating Black PVC		30.80	101.05	66	50	1 10 50 100 200 500 1000	0.42 1.50 3.70 5.40 8.10 13.86 22.80
		0.116	2.95		0.195	4.95						

Coaxial Cylindrical Capacitor



$$C = \frac{2\pi \epsilon_0 \epsilon_r L}{\ln(R_2/R_1)}$$

$$R_2 = 1.5\,\text{mm}$$

$$R_1 = 0.406\,\text{mm}$$

$$\epsilon_r = 2.3\,(\text{polyethylene})$$

$$C = \frac{2\pi\, 8.85\times 10^{-12}\, 2.3}{\ln(1.5/0.4)} = 97\,\text{pf/m}$$

$$C = 2.8\,\text{m} \times 97\,\text{pf/m} = 272\,\text{pf}$$

Conductors a and b are insulated from each other, forming a capacitor. You increase the charge on a to $+2Q$ and increase the charge on b to $-2Q$, while keeping the conductors in the same positions.

What effect does this have on the capacitance C?

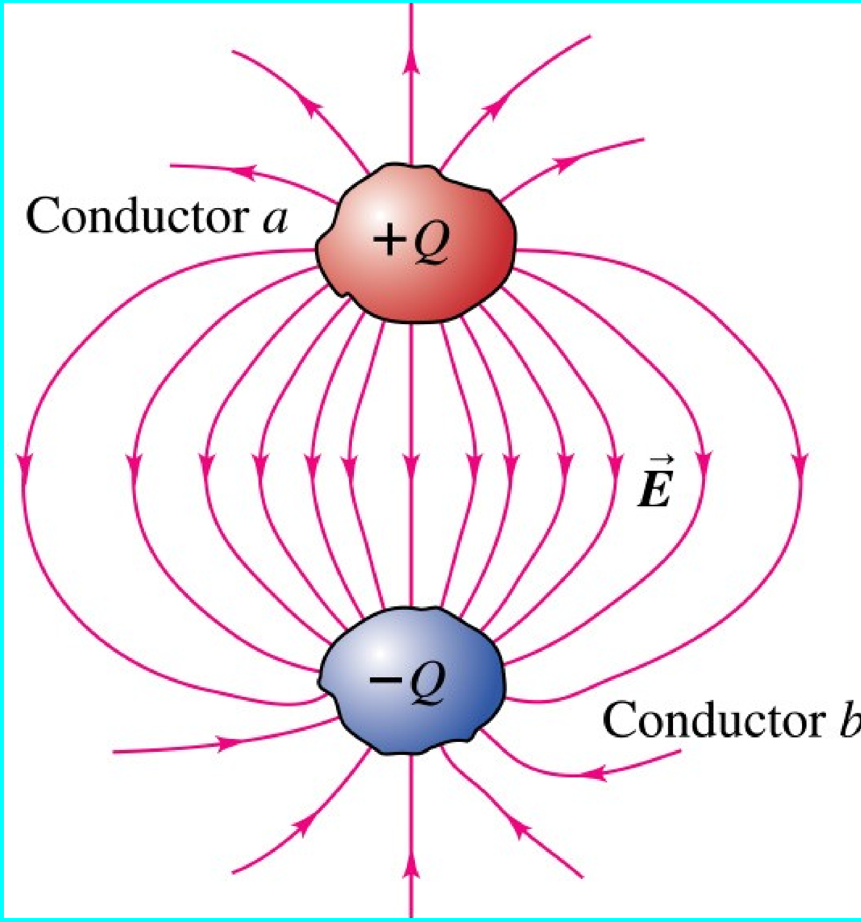
A) C is multiplied by 4

B) C is multiplied by 2

C) C remains the same

D) C is multiplied by ½

E) C is multiplied by ¼



You reposition the two plates of a capacitor so that the capacitance doubles. The charges $+Q$ and $-Q$ on the two plates are kept constant in this process.

What happens to the potential difference V between the two plates?

A) V is multiplied by 4

B) V is multiplied by 2

C) V remains the same

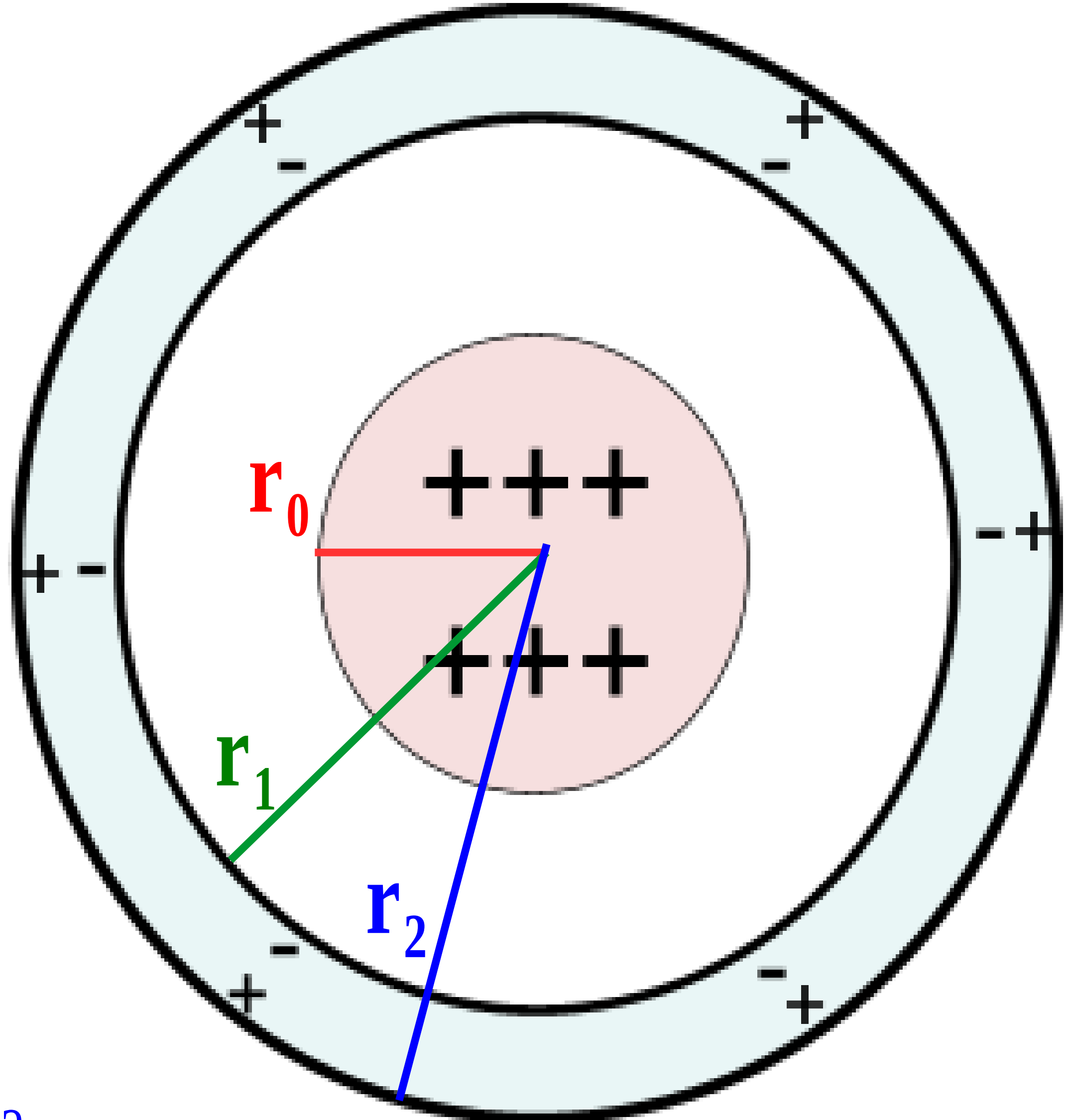
D) V is multiplied by ½

E) V is multiplied by ¼

Potential of a Disk

Conducting sphere of radius r_0 has surface charge density σ_0.

It is then surrounded by a neutral spherical conductor. What are the charge densities at r_1 and r_2



(A) σ_0 and σ_0

(B) $\sigma_0 r_0/r_1$ and $\sigma_0 r_0/r_2$

(C) $\sigma_0 r_1^2/r_0^2$ and $\sigma_0 r_1^2/r_0^2$

(D) $\sigma_0 r_0^2/r_1^2$ and $\sigma_0 r_0^2/r_2^2$