CHARGES DAY 8: CONDUCTORS & SHIELDING

WARMUP **Day 6 Bridge**

State from memory: E inside a conductor at equilibrium = ________, because if it weren't, __________________________. Where does a conductor's net charge live?

THE FIVE CONDUCTOR FACTS

- **E = 0 inside** the metal (charges rearrange until it's true — in ~10^{-19} s).
- Net charge lives **on the surface(s)**.
- At the surface, E is **perpendicular** to the metal — any parallel component would push charge sideways until it vanished.
- Just outside: $\mathbf{E = \sigma/\varepsilon_0}$, with σ the LOCAL surface density.
- σ piles up where the surface curves sharply — **points and edges** carry the strongest fields (lightning rods).

WE DO **Exercise 1: Justify Perpendicularity**

Suppose E at a conductor's surface had a component ALONG the surface. **(a)** What would it do to the surface charges? **(b)** Why does that motion destroy the assumption? **(c)** Conclude the equilibrium direction of E at any metal surface.

INDUCTION: CHARGING WITHOUT TOUCHING

WE DO **Exercise 2: The Four-Panel Story**

A negatively charged rod approaches a neutral conducting sphere on an insulating stand. Draw the four panels: **(1)** rod near, charge redistributed; **(2)** ground wire touched to the far side; **(3)** wire removed, rod still near; **(4)** rod removed. State the sphere's final net charge and its sign.

YOU DO **Exercise 3: Surface Charges, Off-Center**

A +5.0 μC point charge sits INSIDE a neutral conducting shell, but OFF-center. **(a)** Total induced charge on the inner surface (does off-center change it?). **(b)** On the outer surface. **(c)** Is the charge on the outer surface distributed uniformly or lopsided — and why is this the shell "forgetting" where the inside charge sits?

SHIELDING: THE FARADAY CAGE

WHY THE CAGE WORKS

Put a neutral conductor with an empty cavity into an external **electrostatic** field. Surface charges rearrange until $E = 0$ throughout the metal — and Gauss + a line-integral argument (Unit 9) extend that result to the cavity: **for static fields, the field in an empty cavity is exactly zero**, no matter how strong the external field is.

Related, but separate: a metal elevator weakening your phone signal involves rapidly changing fields, which conductors oppose by a different mechanism (induced currents). That story belongs to Unit 13.

For an ISOLATED shell the protection is one-way: a charge inside still projects influence outside, via the charge it induces on the outer surface. Ground the shell and even that vanishes — the outer charge drains away.

WE DO **Exercise 4: Surface Field Numbers**

A conducting sphere of radius 0.5 m carries +2.0 μC. **(a)** σ on its surface (uniform by symmetry): $\sigma = Q/4\pi R^2$ = ________. **(b)** E just outside via σ/ε_0 = ________. **(c)** Check with kQ/R^2 — same number?

CALC **Exercise 5: Two Spheres, One Wire**

Spheres of radius 2.0 m and 0.5 m are connected by a long wire and share +10 μC total. In Unit 9 you'll prove the charge splits so both reach the same potential: $q \propto R$, so the big sphere takes ________ μC and the small ________ μC. **(a)** Fill those in (proportional split). **(b)** Compute E at each surface (kq/R^2) — which sphere has the STRONGER surface field, and what does that say about points and edges?

PAPER PRACTICE

PRACTICE PROBLEMS

P1 Inner and Outer Surfaces

A −4.0 µC charge sits centered in a conducting shell that itself carries +6.0 µC net. Charge on the inner surface? On the outer?

P2 Surface Field

A conducting sphere (R = 1.0 m) carries +4.0 µC. Find σ and the field just outside; confirm the two routes (σ/ε_0 and kQ/R^2) agree.

P3 Cage Reasoning

A charged rod waved around OUTSIDE a closed metal box leaves an electroscope inside dead still. The same rod suspended INSIDE the box makes paper bits cling to the box's outer walls. Explain both directions in two sentences using today's facts.

P4 The Wired Spheres

Spheres R_1 = 3.0 m and R_2 = 1.0 m share +8.0 µC through a wire (split $q \propto R$). Find each sphere's charge and each surface field. The small sphere's field is ________× the big one's.