Electric field inside a conductor (car in lightning)

Physics · Class 12 Physics: Ch 1 Electric Charges and Fields + Ch 2 Electrostatic Potential and Capacitance (electrostatics of conductors)

The trap

✗ Most students think

~~Rubber tyres protect you in a car during lightning, and a charged metal ball has a strong field at its centre.~~

✓ Actually

Charge on a conductor sits on its **outer surface**; inside a closed metal shell **E = 0**. The metal body, not the rubber, is the shield.

The concept in 5 lines

1. Lightning has just crossed **kilometres of air**; a few cm of rubber cannot stop it. Tyres are **not** the shield.
2. The current runs over the car's **outer metal skin** and jumps from the underbody to the wet road. **Don't touch the metal.**
3. **Like charges repel**, so extra charge on a conductor moves to its **outer surface**.
4. Inside a closed conductor nothing pushes: **E = 0** (Gauss: no charge enclosed). This is **electrostatic shielding**.
5. E = 0 inside does **not** mean V = 0: the potential inside equals the surface value, $q / (4\pi\varepsilon_0 R)$.

Remember

Hollow charged sphere: $E = 0$ $(r < R)$ · $E = q / (4\pi\varepsilon_0 r^2)$ $(r \geq R)$

Why it matters

Electrostatic Potential and Capacitance gave NEET **2 to 6 questions a year** (2021 to 2025), Electric Charges and Fields about **27 JEE Main 2025** questions across shifts, and **NEET 2019** asked the hollow-sphere field directly.

Previous-year question, solved

NEET 2019

A hollow metal sphere of radius R is uniformly charged. The electric field due to the sphere at a distance r from the centre:

(A) zero as r increases for r < R, decreases as r increases for r > R

(B) zero as r increases for r < R, increases as r increases for r > R

(C) decreases as r increases for r < R and for r > R

(D) increases as r increases for r < R and for r > R

Answer: zero for r < R, decreases as r increases for r > R

1. All the charge q sits on the outer surface of the metal sphere.
2. Inside (r < R) a Gauss surface encloses **no charge**, so **E = 0** at every point inside.
3. Outside (r > R) it encloses all of q: **$E = q / (4\pi\varepsilon_0 r^2)$**, falling as $1/r^2$.

The option letter differs between paper versions (D on SATHEE, A on ExamSIDE). Match the answer by its wording.

Practice: try each one before you check the answers

Q1 Class 12 A charge of +5 μC is placed on a hollow metal sphere of radius 10 cm. What is the electric field (a) at its centre, (b) at 5 cm from the centre, (c) at 20 cm from the centre? ($1 / 4\pi\varepsilon_0 = 9 \times 10^9$ N m^2 C^{-2})

Q2 JEE pattern A solid metal sphere and a hollow metal sphere of the same radius are given equal charges. Compare the electric field inside them, and the field at a point outside, at the same distance from their centres.

Q3 JEE pattern A point charge +q is placed at the centre of a neutral, hollow metal sphere (inner radius a, outer radius b). What charges appear on the inner and outer surfaces?

Q4 KCET pattern The electric potential inside a charged hollow metal sphere of radius R carrying charge q is: (1) zero (2) $q / (4\pi\varepsilon_0 R)$, the same at every point inside (3) increasing towards the centre (4) decreasing towards the centre

Q5 A / B A charged hollow metal ball. Is the electric field at its centre zero or strong? (A) Zero (B) Strong

Answers

1. **(a) 0, (b) 0, (c) 1.125 × 10⁶ N/C.** Points (a) and (b) are inside the shell, where no charge is enclosed, so E = 0. At 20 cm: $E = 9 \times 10^9 \times 5 \times 10^{-6} \div (0.2)^2 = 45 \times 10^3 \div 0.04 = 1.125 \times 10^6$ N/C, pointing away from the centre.
2. **Exactly the same.** In both, all the extra charge moves to the outer surface, so the field is zero everywhere inside and $q / (4\pi\varepsilon_0 r^2)$ outside. A conductor does not care whether its middle is solid metal or empty space.
3. **−q on the inner surface, +q on the outer surface.** The field inside the metal itself must be zero, so a Gauss surface drawn inside the metal must enclose zero net charge: the inner surface carries −q. The sphere is neutral overall, so +q appears on the outer surface. Shielding works from outside to inside: a charge outside a closed shell cannot create a field inside it; a charge you place inside still has its own field.
4. **(2) $q / (4\pi\varepsilon_0 R)$, the same everywhere inside.** E = 0 inside means no work is done moving a charge there, so the potential does not change: it stays equal to its value at the surface. A very common trap: **E = 0 does not mean V = 0.**
5. **A, zero.** Like charges push each other apart, so all the charge sits on the ball's outer surface. Inside the closed metal shell nothing pushes: the field at the centre, and everywhere inside, is zero. It is the same reason the four people in the taxi were safe.

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