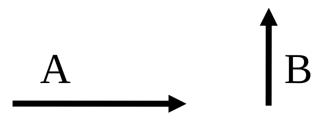
CTGAUSS-1.

Two vectors **A** and **B** are perpendicular to each other.

The dot product **A·B** is equal to..



A) AB B) zero C) –AB

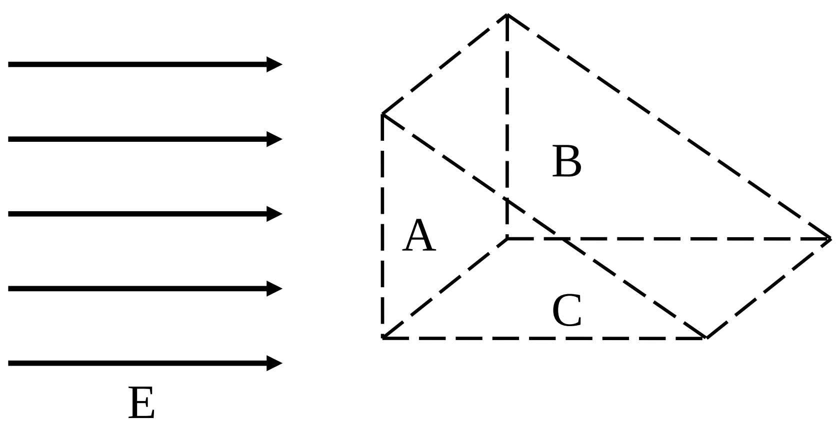
D) Answer depends on the locations of the two vectors

E) Some other answer

Answer: zero Be sure you understand the definition of the dot product.

CTGAUSS-2.

A prism-shaped closed surface is in a constant, uniform electric field **E**, filling all space, pointing right. The 3 rectangular faces of the prism are labeled A, B, and C. Face A is perpendicular to the E-field. The bottom face C is parallel to **E**. Face B is the leaning face. (The two triangular side faces are not labeled.)



Which face has the largest magnitude electric flux through it?

A) A B) B C) C

D) A and B have the same magnitude flux

Answer: A and B have the same magnitude flux. The magnitude of the flux through a surface is proportional to the number of field lines through the surface. (See online lecture notes for proof.)

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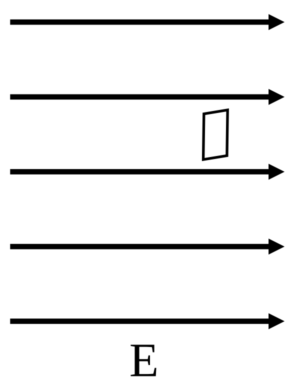
CTGAUSS-3.
There is a constant uniform E-field represented by the field lines shown. A small square surface is placed as shown, with the surface perpendicular to the direction of the E-field. Is there a non-zero flux through the surface?



A) Yes, flux ≠ 0 B) No, flux = 0

Answer: Yes, there is a non-zero flux. Even though no field lines happen to go through the surface in this diagram, there is a field everywhere in space, including at the location of the surface.

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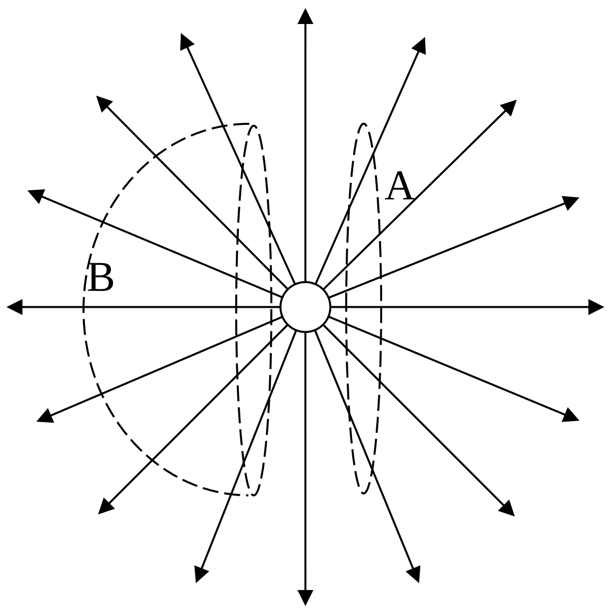
CTGAUSS-4. Two open surfaces are in an electric field as shown. Surface A is a flat circular disk of radius R, which squarely faces the charge. Surface B is a hollow-cup hemisphere of the same radius R. The flat rim of the hemisphere is the same distance from the charge as the rim of the flat disk. Which surface has the greater flux through it?



A) A

B) B

C) Both surfaces have the same flux.

Answer: Both surfaces have the same flux, since both have the same number of field lines passing through them.

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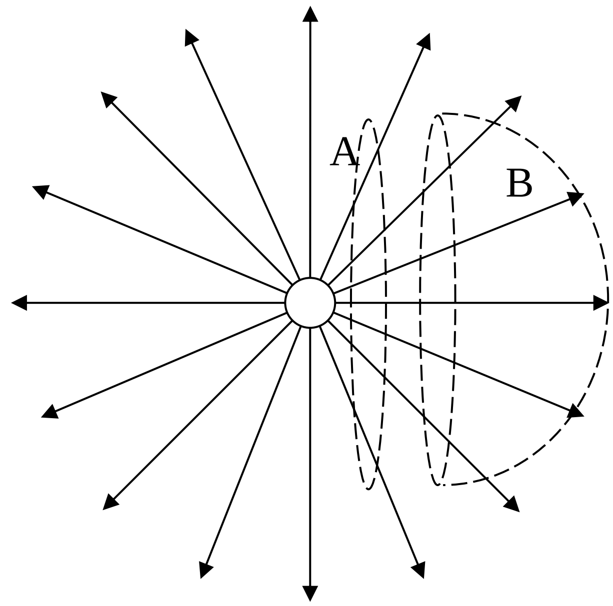
CTGAUSS-5. Two open surfaces are in an electric field as shown. Surface A is a flat circular disk of radius R. Surface B is a hollow-cup hemisphere of the same radius R. Which surface has the greater flux through it?

A) A

B) B

C) Both surfaces have the same flux.

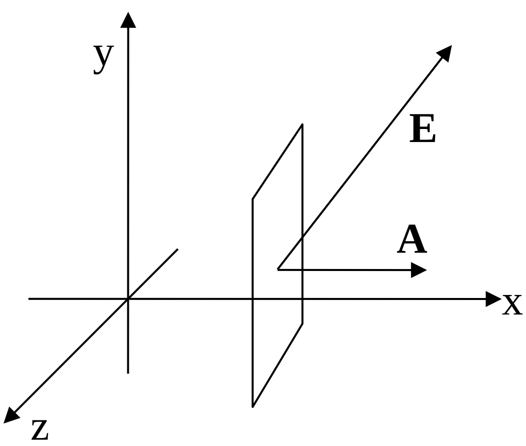


Answer: A has greater flux, since it contains more field lines.

CTGAUSS-6.

The flux thru an area $\vec{A} = A\,\hat{x}$, where the electric field is $\vec{E} = E_x\,\hat{x} + E_y\,\hat{y}$

(E_x and E_y are constants), is ...



A) $\left(\sqrt{E_x^{\ 2} + E_y^{\ 2}}\right)(A)$

B) $\left(E_x + E_y\right)(A)$

C) $E_x\ A$

D) $E_y\ A$

E) None of these.

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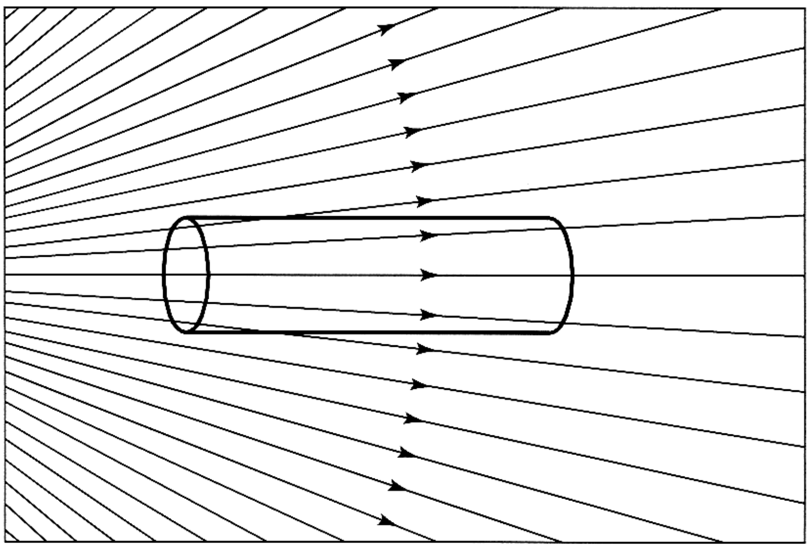
Answer: $E_x A$ For any two vectors $\vec{E}$ and $\vec{A}$, the dot product in cartesian coordinates is $\vec{E} \cdot \vec{A} = E_x A_x + E_y A_y + E_z A_z$. In this problem, $A_y = 0$, $A_z = 0$, and $A_x = A$.

CTGAUSS-7. The net electric flux flowing through the closed cylindrical surface shown is:

A) Zero B)Positive C) Negative



Answer: net flux is zero. Two ways to see this:

1) number of field lines in = number of field lines out, so net flux is zero

2) enclosed charge is zero (since no field lines start or stop inside), so by Gauss's Law the net flux must be zero.

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CTGAUSS-8. The non-zero electric field everywhere on a closed surface is constant: $\vec{E} = \text{constant}$ (meaning vector $\vec{E}$ is everywhere constant in magnitude and direction). Is the following calculation correct?

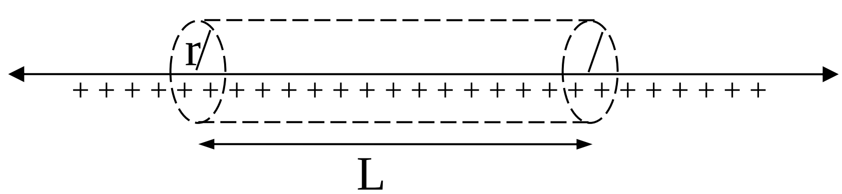
$$\oint \vec{E} \cdot d\vec{a} = \oint E\,da = E\oint da = EA$$

A) Definitely correct B) Definitely incorrect

C) Possibly correct, possibly incorrect – depends on details of the surface and **E**.

Answer: The answer is B) Definitely incorrect. In order for, $\oint \vec{E} \cdot d\vec{a} = \oint E\,da = E\oint da = EA$ to be true, two conditions must be satisfied: 1) the vector **E** must be parallel to the vector d**a** *everywhere* on the surface , and 2) the magnitude E must be constant everywhere on the surface. Condition (1) is impossible to satisfy for any closed surface if the vector **E** has only a single constant direction.

CTGAUSS-9. To compute the E-field around an infinite line of charge (with charge per length λ) a student draws the cylindrical gaussian surface of radius r and length L.



What is $\oint \vec{E} \cdot d\vec{a}$ for this surface?

A) $E\,2\pi r^2$ B) $E\,2\pi r L$ C) $E(2\pi r^2 + 2\pi r L)$

D) $E\,\pi r^2$ E) None of these

Answer: $E\,2\pi r L$ This is the area of the curved side of the cylinder. The flat end caps of the cylinder make no contribution to the integral since on the end caps, $\vec{E} \perp d\vec{a}$.

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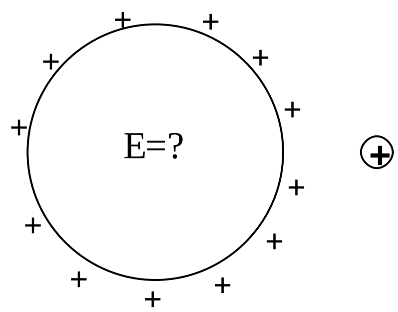
CTGAUSS-10. A spherical shell with a uniform positive charge density on its surface is near a positive point charge. Is the electric field inside the sphere zero?



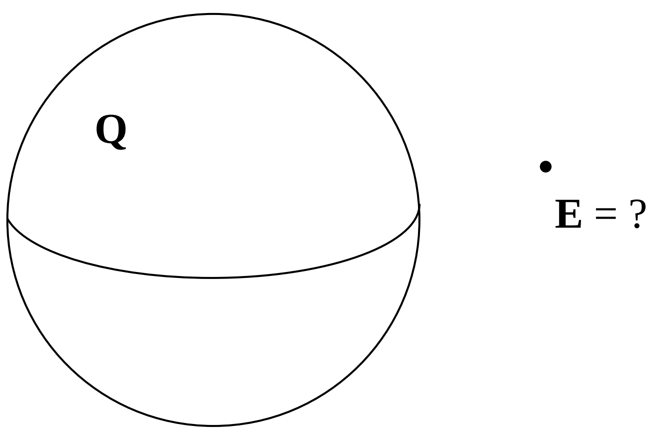
A) E=0 inside

B) $E \neq 0$ inside

C) Not enough info to answer.

Answer: $E \neq 0$ inside. The total E-field is the vector sum of (the field due to spherical shell of charge) + (the field due to the point charge). The field due to the spherical shell is zero (inside the shell). But the field due to the point charge is present inside the shell.

CTGAUSS-11. What is the electric field at a point in empty space **outside** a spherically symmetric distribution of charge with total charge Q?



A) zero

B) same that produced by a single point charge Q at the center of the sphere

C) different than a single point charge Q at the center of the sphere

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Answer: B. You can use Gauss's Law to prove that the E-field outside a spherical distribution of total charge Q is the same E-field would be produced by a point charge Q at the center of the sphere.

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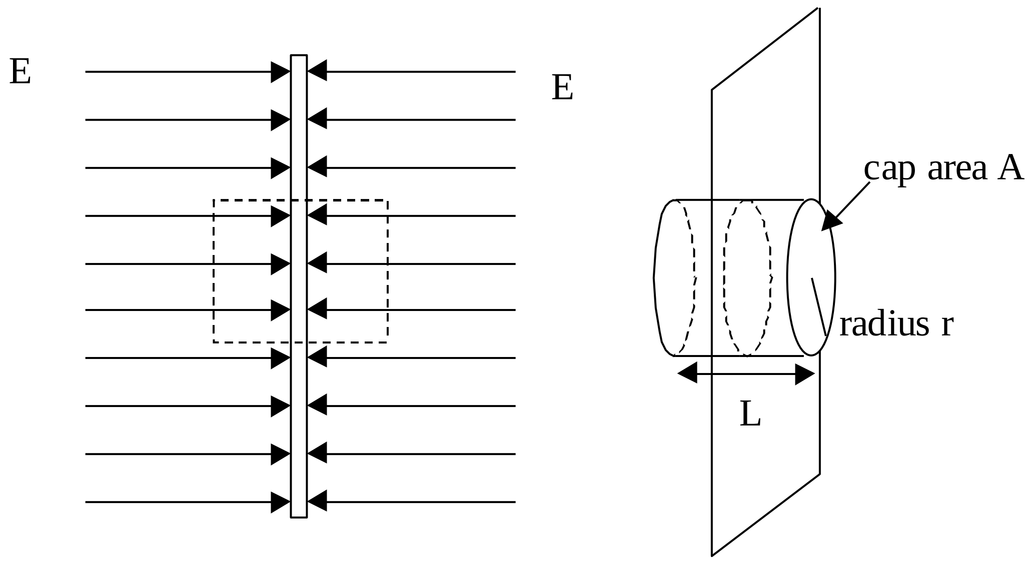
CTGAUSS-12. A uniform, infinite plane of <u>negative</u> charge creates a uniform E-field of magnitude E perpendicular to the plane and pointing toward the plane as shown. An imaginary gaussian surface in the shape of a right cylinder is shown. (This shape is sometimes called a "pillbox".) The flux through surface is..



A) –EA B) +2EA C) $(-2A+L\pi r^2)$ E

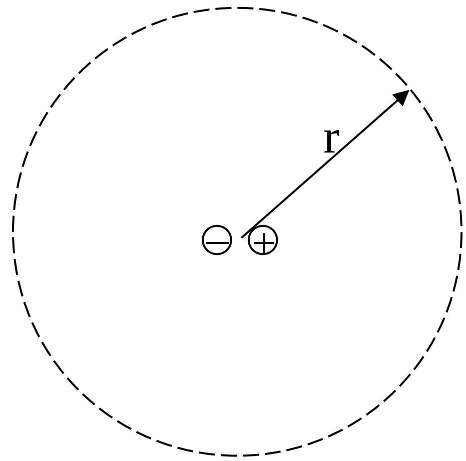
D) $L\pi r^2E$ E) None of these

HINT: It's a trick question.

Answer: None of these. The answer is –2EA (the flux through the flat end caps is negative)

CTGAUSS-13. A dipole sits near the origin. We draw an imaginary Gaussian sphere (radius r) around it. Gauss' law says:

$$\oint \vec{E} \cdot d\vec{a} = \frac{q_{enclosed}}{\varepsilon_0}$$



Do we conclude that E=0 everywhere on that sphere?

A) Yes, E=0 everywhere

B) No, E is not 0 at all points on that sphere.

Answer: No, E is not zero at all points on that sphere. The total flux through the sphere is zero, but the E is non-zero everywhere on the sphere. In some places on the sphere, the flux is positive, in other places, it is negative. The total flux sums to zero.

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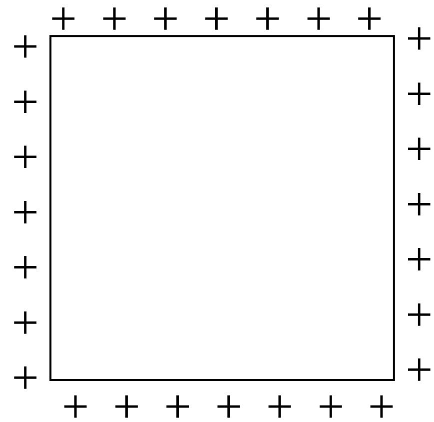
CTGAUSS-14. Suppose we tried to use Gauss's Law to determine the E-field inside closed cube with uniform surface charge density on its surface (no charge is inside the cube)?



Is there any imaginary Gaussian surface for which we can argue that

$$\oint \vec{E} \cdot d\vec{a} = \oint E\, da = E \oint da = EA$$

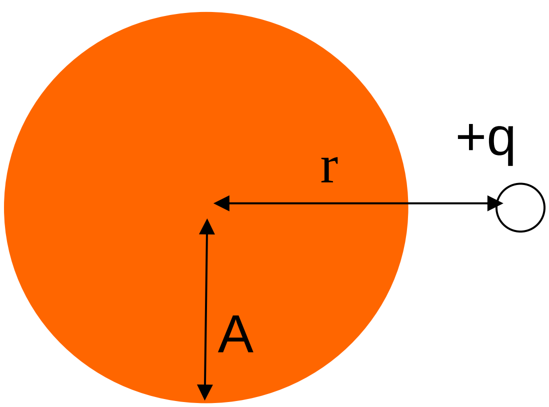
?

A) Yes, so we can use Gauss's Law to compute the E-field.

B) No, so Gauss's Law doesn't help us compute the E-field.

Answer: No, E is not zero everywhere inside. With the sphere, we were able to argue from symmetry that $\oint \vec{E} \cdot d\vec{a} = EA$ for the imaginary spherical surface. In the case of a cube, we cannot make the same symmetry argument regardless of which imaginary Gaussian surface we pick.

CTGAUSS-15. A point charge +q sits outside a solid *neutral* copper sphere of radius A. What is the magnitude of the E-field at the center of the sphere?



A) $E = kq/r^2$

B) $E = kq/A^2$

C) $E = kq/(r-A)^2$

D) $E = 0$

E) None of these

Answer: $E = 0$ everywhere inside a metal in equilibrium. Polarization charges form on the surface of the copper sphere which produce a field inside the copper which exactly cancels the field due to the point charge q.

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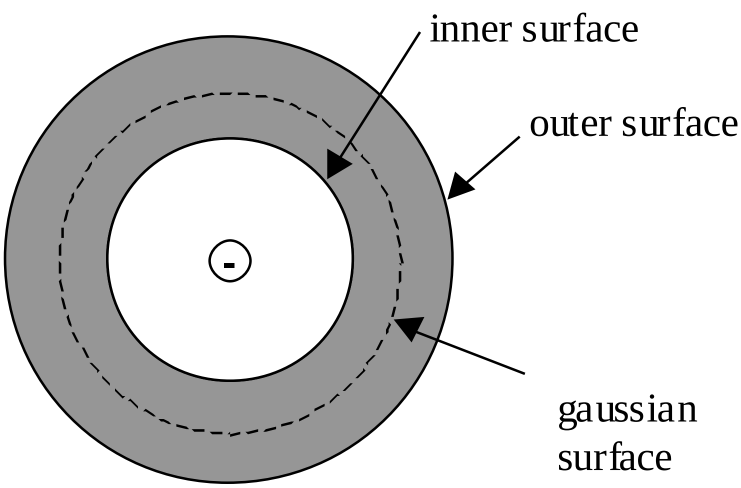
CTGAUSS-16. A negative point charge with

charge -Q sits in the interior of a spherical metal shell. The conducting metal shell has no net charge. What is the total charge on the inner surface of the shell?



A) –Q

B) +Q

C) +2Q

D) zero

E) Some other answer.

Hint: Consider the gaussian surface shown.

What is the total charge on the **exterior** surface of the shell?

A) –Q B) +Q C) +2Q D) zero E) Some other answer.

Answers: Total charge on the inside surface is +Q. You can prove this with Gauss's Law applied to the imaginary gaussian surface inside the metal. The total charge on the outside surface is –Q, since the total charge on the metal must be zero (+Q –Q = 0)

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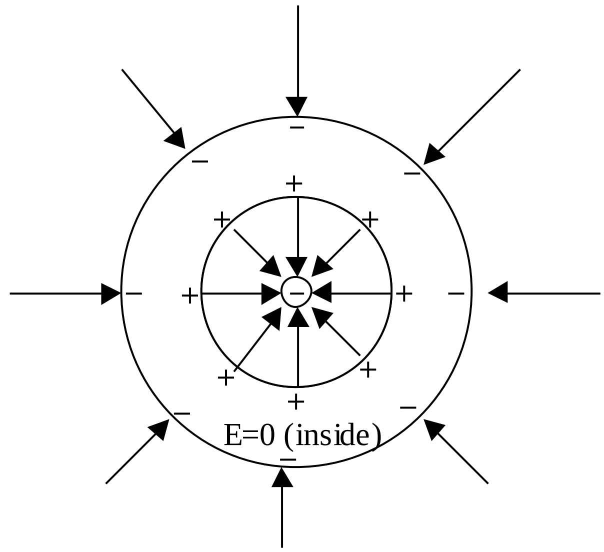
The field lines looks like this:



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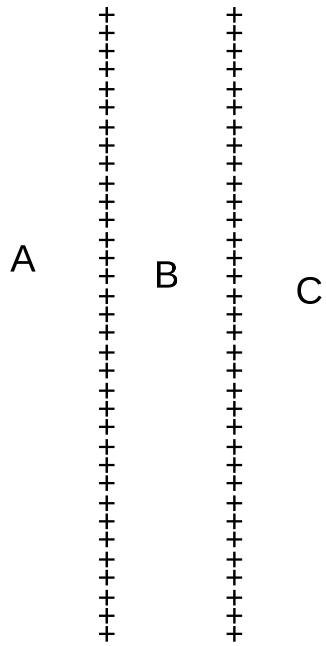
CTGAUSS-17. Two infinite planes are uniformly charged with the same charge per area σ. If one plane only were present, the field due to the one plane would be E.



The field in region B has magnitude…

A) zero B) E C) 2E

D) depends on exact position.

The field in region A has magnitude…

A) zero B) E C) 2E

D) depends on exact position.

Answers: The field in region B is zero because the fields from the two planes cancel in that region. The field in region A is 2E because in A the fields from the two planes are in the same direction and they add.

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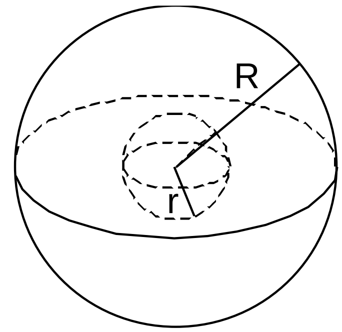
CTGAUSS-18.



An insulating sphere of radius R has a total charge +Q spread uniformly throughout its volume. The charge density is $\rho = \dfrac{Q}{(4/3)\pi R^3}$.

(The sphere must be an insulator, because it can't be a metal. Why not?) We are going to compute the electric field magnitude E within the sphere.

What is the charge enclosed by the centered small sphere of radius r?

A) $Q(4/3)\pi r^3$ B) $Q\dfrac{r^2}{R^2}$ C) $Q\dfrac{r^3}{R^3}$ D) $Q\dfrac{R^3}{r^3}$

E) None of these.

If the electric field at distance r from the center of the sphere has magnitude E, what is the flux $\oint \vec{E}\cdot d\vec{a}$ through the small sphere, radius r?

A) $E(\pi R^2)$ B) $E(\pi r^2)$ C) $E(4\pi R^2)$ D) $E(4/3)\pi r^2$ E) None of these.

Within the sphere, the electric field magnitude E is proportional to

A) r B) r^2 C) r^3

D) None of these, E=constant within the sphere.

E) None of these, E=0 within the sphere.

Answers: $q_{\text{enclosed}} = Q\dfrac{r^3}{R^3}$, this is the total charge Q times the fraction (r^3/R^3) of the volume taken up by the small sphere.

The flux through the small sphere is $E(4\pi r^2)$ [None of these],

Inside the sphere, $E \propto r$. Gauss's Law says $\oint \vec{E}\cdot d\vec{a} = q/\varepsilon_o \quad \Rightarrow \quad E(4\pi r^2) = Q\dfrac{r^3}{R^3}\cdot\dfrac{1}{\varepsilon_o}$

Solving for E gives $E = \left(\dfrac{Q}{4\pi R^3\,\varepsilon_o}\right) r, \qquad \text{for} \quad r < R$.

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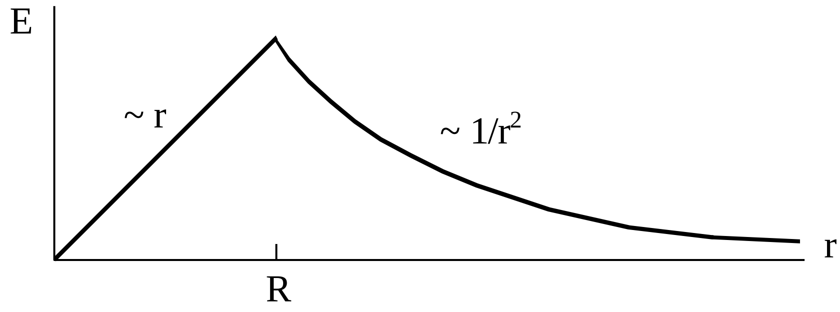
It is easy to show, from Gauss's Law, that, outside the big sphere, r > R, the E-field is just that due to a point charge Q,

$$E_{outside} = \frac{Q}{4\pi\varepsilon_0 r^2}$$



CTGAUSS-19. Three closed surfaces enclose a point charge. The three surfaces are a small cube, a small sphere, and a larger sphere – all centered on the charge. Which surface has the largest flux through it?

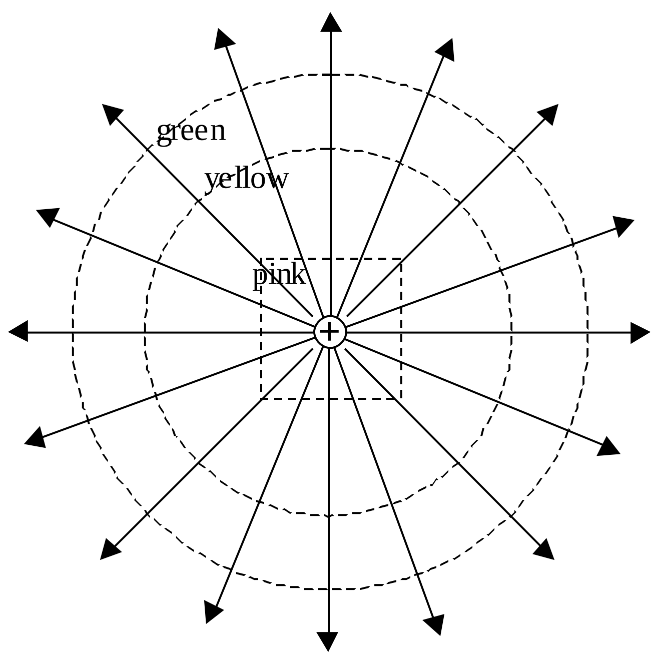
A) Small cube

B) smaller sphere

C) larger sphere

D) Impossible to tell without more information

E) All three have the same flux.



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Answer: All three have the same flux, since all three enclose the same charge. And the same number of field lines pass through each surface.

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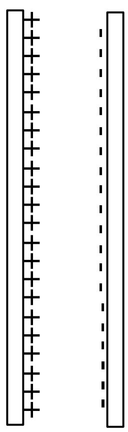
CTGAUSS-20. A ***capacitor*** consists of two parallel metal plates that have been charged up with equal and opposite charges: +Q on one plate, –Q on the other. All the excess charge resides on the inside surfaces as shown. (Why no charge on the outside surfaces?... Because opposite charges attract.)



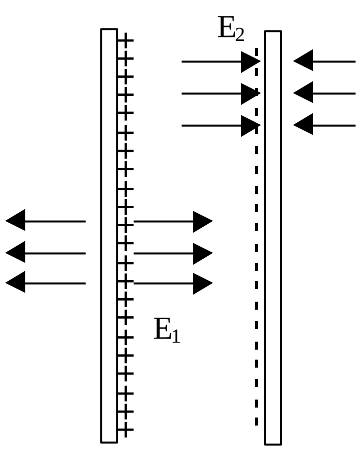
The surface charge density on each plate is of magnitude σ. (+σ on the inside left plate, –σ on the inside right plate.) If the plates are large enough, "edge effects" are small and the magnitude of the electric field between the plates is nearly uniform.

What is the magnitude of the electric field in the space between the plates?

A) $\dfrac{\sigma}{\varepsilon_o}$ B) $\dfrac{\sigma}{2\varepsilon_o}$ C) $\dfrac{2\sigma}{\varepsilon_o}$

D) Some other answer.

Answer: $\dfrac{\sigma}{\varepsilon_o}$



We can see this answer is two ways:

1) The E-field outside a charged metal surface in electrostatic equilbrium is always $\dfrac{\sigma}{\varepsilon_o}$.

2) The E-field due to a single plane of charge is $E = \sigma/(2\varepsilon_o)$. In this problem, there are two planes of charge: the left plane, plane 1, and the right plane, plane 2. The total electric field is the vector sum of the fields due to the two planes: $\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2$. Every between the plates, the fields add and $E_{tot} = \sigma/(2\varepsilon_o) + \sigma/(2\varepsilon_o) = \sigma/\varepsilon_o$. Everywhere outside the plates, the fields due to the two planes are in opposite directions and cancel, $E_{tot} = 0$.

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CTGAUSS-21. Consider the following statements:

I) If $\oint_S \vec{E} \bullet d\vec{a} = 0$ for a closed surface S, then E=0 everywhere on surface S.

II) If E=0 everywhere on a closed surface S, then $\oint_S \vec{E} \bullet d\vec{a} = 0$ for the surface S.

Which of these statements are true?

A) Both B) Neither C) I only D) II only

Answer: Statement I is false. Statement II is true. To see why statement I is false, consider a closed spherical surface with a point charge outside the sphere and no charge inside.

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