

Exam 1 Solutions

1. Two identical conducting spheres A and B carry identical charges. They are separated by a distance much larger than their diameters. A third identical conducting sphere C is uncharged. Sphere C is first touched to A, then to B and finally removed. As a result, the electrostatic force between A and B, initially F , becomes

- (1) $3F/8$
- (2) F
- (3) $F/2$
- (4) $F/16$
- (5) 0

Let the initial charge on A and B be called Q . When C is touched to A, because they are identical they each half the total charge or $Q/2$. Similarly, when C is then touched to B, they each get half the total charge or $3Q/4$. Since A and B now have charges $Q/2$ and $3Q/4$, respectively, the force between them becomes $3/8$ of its initial value.

2. Two charged point particles are located at two vertices of an equilateral triangle and the electric field is zero at the third vertex. We conclude

- (1) at least one other charge is present
- (2) the two particles have charges with opposite signs and the same magnitude
- (3) the two particles have charges with opposite signs and different magnitudes
- (4) the two particles have identical charges
- (5) the two particles have charges with the same sign and different magnitudes

When only two charges are present, the electric field at the third vertex cannot be zero, as can be seen by noting that either the x or y components of the field can be cancelled (by suitably choosing the charges at the other two vertices to be equal or opposite sign), but not both. Thus another charge is needed to cancel the E field.

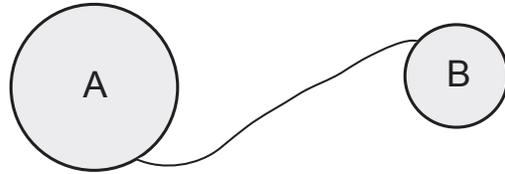
3. A nonconducting sphere of radius R has charge Q spread uniformly throughout its volume. If the magnitude of the electric field at the surface is E , what is the magnitude of the electric field at $r = R / 4$?

- (1) $E / 4$
- (2) $E / 2$
- (3) $2E$
- (4) E
- (5) $4E$

In order to find E_r , the E field at $r = R / 4$, we take the Gaussian surface to be a sphere at $r = R / 4$. From Gauss' law, we obtain $4\pi r^2 E_r = q_{\text{enc}} / \epsilon_0$. However, at $r = R / 4$, $q_{\text{enc}} = Q / 64$, thus $E_r = Q / 16\pi R^2 \epsilon_0$. Since $E = Q / 4\pi R^2 \epsilon_0$, we get $E_r = E / 4$.

4. Two charged metal spheres are connected by a copper wire, as shown in the figure. Note that $r_A = 4r_B$ and the spheres are far apart. What is the ratio Q_A / Q_B of charges?

- (1) 4
- (2) 2
- (3) 1
- (4) 1/4
- (5) 1/2



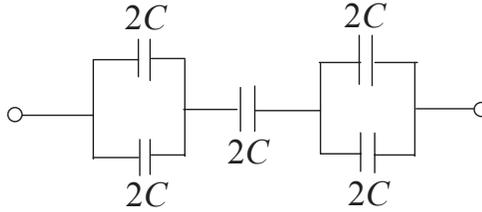
The electric potential must be a constant for a conductive surface. Thus, the two surfaces connected by a copper wire must be at the same electric potential (if they were not, charge would flow).

$$V = k \frac{Q_A}{r_A} = k \frac{Q_B}{r_B}$$

$$Q_A / Q_B = r_A / r_B = 4$$

5. Five capacitors are connected as shown in the figure. The equivalent capacitance of the arrangement is:

- (1) C
- (2) $2C$
- (3) $9C$
- (4) $2C/5$
- (5) $4C$



First find the equivalent capacitances for capacitors 1 and 3 to get $4C$ for each of them. Then add the three resulting capacitances in series to obtain, $1/C_{tot} = 1/4C + 1/2C + 1/4C$ or $C_{tot} = C$.

6. The charge neutral He atom has 2 electrons/atom. How much negative and positive charge is there (in coulombs), respectively, in a mole of He?

- (1) -1.9×10^5 , 1.9×10^5
- (2) -9.6×10^4 , 9.6×10^4
- (3) -1.9×10^5 , 9.6×10^4
- (4) -1.2×10^{24} , 1.2×10^{24}
- (5) -1.2×10^{24} , 6×10^{23}

A mole of He has 6×10^{23} atoms or 1.2×10^{24} electrons and 1.2×10^{24} protons of opposite charge. The total amount of negative and positive charge is obtained by multiplying each of these numbers by $-e$ and $+e$, respectively, where $e = 1.6 \times 10^{-19}$ C.

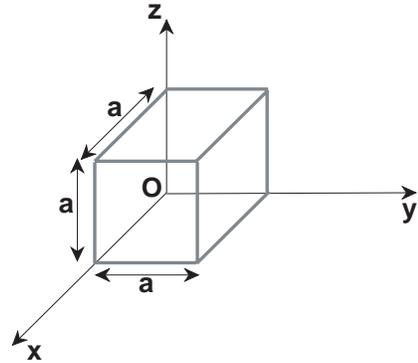
7. An electron traveling with velocity $4000\hat{i}$ m/s, enters a region of uniform electric field $1 \times 10^{-8}\hat{j}$ N/C. After 3 sec, what is the speed of the electron in m/s?

- (1) 6600
- (2) 5300
- (3) 4000
- (4) 9300
- (5) 2600

The initial velocity v_0 of the electron is in the x direction and the force acting on the electron is in the y direction, perpendicular to its initial direction. The velocity in the y direction is thus $(eE/m)t$, where the quantity in parentheses is the acceleration. The

total velocity is thus $v = \sqrt{v_0^2 + (eE/m)^2 t^2} = 6600$ m/s.

8. A cube having edge length 2 m is oriented as shown in the figure with its back bottom left corner at the origin with the edges associated with that corner lying along each of the 3 coordinate axis. The electric field in that region of space is a uniform $10\hat{k}$ N/C. The electric flux (in Nm^2/C) through the bottom face (in the \hat{i}, \hat{j} plane) and the charge (in C) enclosed in the cube are, respectively?



- (1) $-40, 0$
- (2) $-10, 0$
- (3) $-40, 7 \times 10^{-10}$
- (4) $10, 2 \times 10^{-10}$
- (5) -10 , insufficient info

The flux through the bottom face is $\vec{E} \cdot \vec{A} = -EA = -40$. The negative sign arises because the normal to the surface is outward (down) and the E field is pointing upward. The total flux through the top and bottom faces is zero, and there is no contribution from the other four faces (normals are perpendicular to E), thus by Gauss' law the total enclosed charge is zero.

9. What is the electric potential energy (in J) of two protons, in deep space, 0.5 m apart from each other?

- (1) 4.6×10^{-28}
- (2) 9.2×10^{-28}
- (3) 9.6×10^{-27}
- (4) 5.6×10^{-26}
- (5) 4.4×10^{-38}

10. The capacitance of a parallel-plate capacitor is:

- (1) directly proportional to the plate area
- (2) directly proportional to the charge stored
- (3) independent of any material inserted between the plates
- (4) directly proportional to the potential difference of the plates
- (5) directly proportional to the plate separation

The capacitance is $C = \kappa\epsilon_0 A/d$, so it is proportional to the plate area and inversely proportional to the plate separation. It also depends on the material inserted between the plates.