Institutt for fysikk, NTNU
TFY4155/FY1303: Elektrisitet og magnetisme
Vår 2004

Øving 8

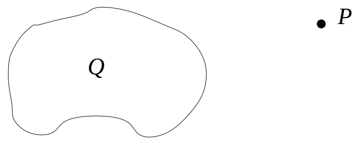
Guidance: 23.02, (24.02), 25.02, 26.02, 27.02, 01.03, 03.03, 04.03
To be delivered by: Thursday March 4 kl. 1200 (Table for your answers on the last page.)

Information:

- Unless otherwise stated, it is assumed that the system is in electrostatic equilibrium.
- Unless otherwise stated, "potential" means "electrostatic potential", and correspondingly for "potential energy".
- Unless otherwise stated, zero (electrostatic) potential and potential energy is chosen infinitely far away.
- You may need some of these: $1/4\pi\varepsilon_0 = 9 \cdot 10^9$ Nm^2/C^2, $e = 1.6 \cdot 10^{-19}$ C, $m_e = 9.11 \cdot 10^{-31}$ kg, $m_p = 1.67 \cdot 10^{-27}$ kg, $g = 9.8$ m/s^2
- Symbols are given in italics (e.g. V for potential) while units are given without italics (e.g. V for volt).

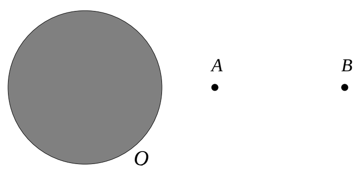
1) An arbitrarily shaped conductor has net charge Q. What happens in the point P if the charge on the conductor is increased to $2Q$?

A Only the potential is doubled.
B Only the electric field strength is doubled.
C Both the potential and the electric field strength are doubled.
D Neither the potential nor the electric field strength is doubled.
E Both the potential and the electric field strength are halved.



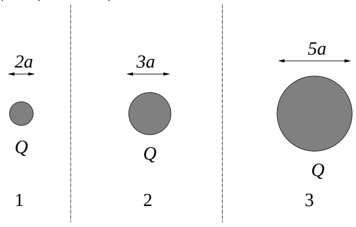
2) A compact metal sphere has positive charge Q. The distance from the center of the sphere to the point A is half the distance to point B. Zero potential is chosen at infinity. Then we have for the electric field strength E and the potential V in the two points:

A $E_A = 4E_B$, $V_A = 4V_B$
B $E_A = 4E_B$, $V_A = 2V_B$
C $E_A = 4E_B$, $V_A = V_B$
D $E_A = 2E_B$, $V_A = 2V_B$
E $E_A = E_B$, $V_A = V_B$



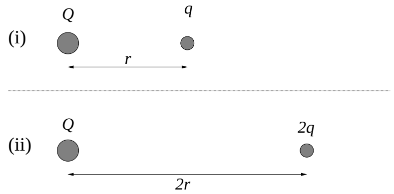
3) Three isolated metal spheres 1, 2, and 3 (i.e., they do not influence *each other*) each have a positive charge Q. The diameter of the spheres is $2a$, $3a$, and $5a$, respectively. How is the potential on the three spheres related to each other? ($V(\infty) = 0$)

A $V_1 = V_2 = V_3$
B $V_1 < V_2 < V_3$
C $V_1 > V_2 > V_3$
D $V_1 = V_2 < V_3$
E $V_1 = V_2 > V_3$



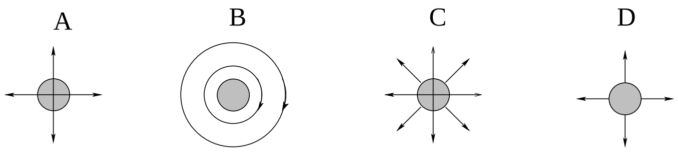
4) Imagine two different experiments, both starting with to isolated, identical point charges Q: (i) A (positive) point charge q is brought from infinitely far away to a distance r from one of the Qs. (ii) A (positive) point charge $2q$ is brought from infinitely far away to a distance $2r$ from the other Q. When these two experiments have been performed, what is then *not* true?

A The potential at distance r (i.e., where the charge q is) is the same as the potential at distance $2r$ (i.e., where the charge $2q$ is).
B In the two experiments, the work done is the same.
C In the two experiments, we end up with the same potential energy.
D The charge q at distance r is influenced by a larger repulsive force than the charge $2q$ at distance $2r$.
E The ratio between the forces acting on q and $2q$ is not the same as the ratio between the electric field strengths at distance r and $2r$.



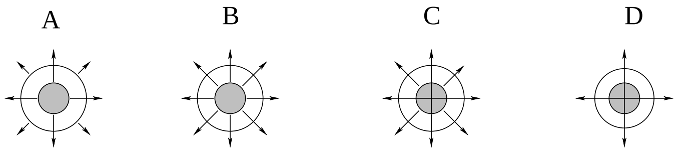
5) The correct figure shows electric field lines in a plane passing through the center of a metal sphere with net charge $Q > 0$.

A
B
C
D



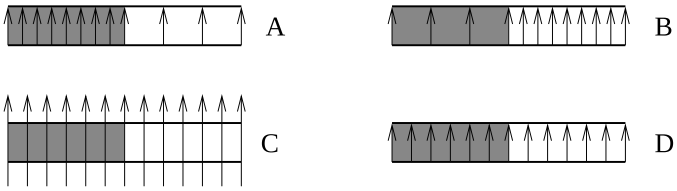
6) The correct figure shows electric field lines in a plane passing through the center of a charged metal sphere ($Q > 0$) uniformly covered by a layer of (electrically neutral) plastic (with $\varepsilon > \varepsilon_0$). The surrounding medium is air.

A
B
C
D



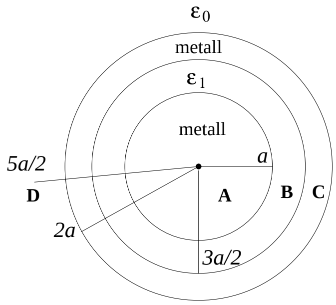
7) The correct figure shows electric field lines for a parallel plate capacitor that is half filled with a dielectric (i.e., the hatched region has $\varepsilon > \varepsilon_0$). The linear dimension of the plates is large compared to the distance between the plates. The upper plate has negative charge $-Q$, the lower plate has positive charge Q.

A
B
C
D



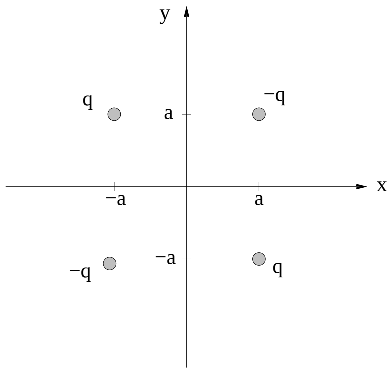
8) A compact metal sphere with radius a has a net charge $q > 0$. It is covered with a layer of (electrically neutral) plastic with thickness $a/2$. Outside follows an (electrically neutral) metallic spherical shell of thickness $a/2$. Outside this, we have vacuum. The plastic is a dielectric with permittivity $\varepsilon_1 = 10\varepsilon_0$. In which of the 4 labeled positions **A**, **B**, **C** or **D** is the electric field strength largest? The distance from the center of the sphere is in **A**: $a/2$, **B**: $5a/4$, **C**: $7a/4$, **D**: $5a/2$.

A
B
C
D



9) Four point charges are located in the xy plane. Two of them have positive charge q and lie in $(x, y) = (a, -a)$ and $(-a, a)$. The two others have negative charge $-q$ and lie in $(x, y) = (a, a)$ and $(-a, -a)$. What is the direction of the electric field $\boldsymbol{E}$ on the x axis (assume $x > a$), i.e., in $(x, 0)$?

A Along $\hat{x}$.
B Along $-\hat{x}$.
C Along $\hat{y}$.
D Along $-\hat{y}$.
E It depends upon x.

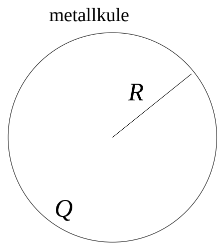


10) For the system with the four point charges in exercise 9, we choose zero electric potential, $V = 0$, at infinity. What is then $V(x, y = 0)$, i.e., on the x axis?

A $V = 0$
B $V = q/4\pi\varepsilon_0 x$
C $V = q/\pi\varepsilon_0 x$
D $V = q/4\pi\varepsilon_0\sqrt{(x-a)^2 + a^2}$
E $V = -q/4\pi\varepsilon_0\sqrt{(x-a)^2 + a^2}$

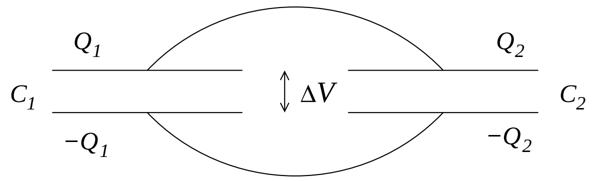
11) A metallic sphere with radius R carries a net charge Q. What is the potential energy U of the sphere? (We choose $U = 0$ when all infinitesimal contributions to Q are infinitely far away from each other.)

A $U = -Q^2/\pi\varepsilon_0 R$
B $U = -Q^2/8\pi\varepsilon_0 R$
C $U = Q^2/\pi\varepsilon_0 R$
D $U = Q^2/8\pi\varepsilon_0 R$
E $U = Q^2/4\pi\varepsilon_0 R^2$



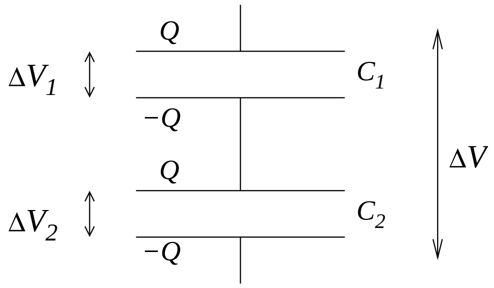
12) Two parallel plate capacitors are connected in *parallel*, as shown in the figure. The upper metal plates are connected via an electric conductor (e.g. a copper wire) so that these two plates "lie" on the same electric potential. The same applies to the two lower metal plates. Therefore, the potential difference (or *the voltage drop*) ΔV is the same for the two capacitors. What is the total capacitance C for two such capacitors connected in parallel? (The two capacitors have capacitances C_1 and C_2, respectively.)

A $C_1 - C_2$
B $C_1 + C_2$
C $(C_1 + C_2)/2$
D $(1/C_1 - 1/C_2)^{-1}$
E $(1/C_1 + 1/C_2)^{-1}$



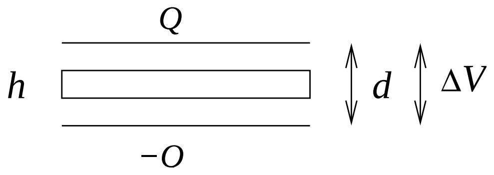
13) Two parallel plate capacitors are connected in *series*, as shown in the figure. The lower metal plate of capacitor 1 is connected to the upper metal plate of capacitor 2 via a conductor (e.g. a copper wire) so that these two plates "lie" on the same electric potential. The total potential difference (or *voltage drop*) ΔV across the two capacitors equals the sum of the voltage drops ΔV_1 and ΔV_2 across each of the two. The net charge on the various metal plates is as shown in the figure. What is the total capacitance C for two such capacitors connected in series? (The two capacitors have capacitances C_1 and C_2, respectively.)

A $C_1 - C_2$
B $C_1 + C_2$
C $(C_1 + C_2)/2$
D $(1/C_1 - 1/C_2)^{-1}$
E $(1/C_1 + 1/C_2)^{-1}$



14) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have charge Q and $-Q$, respectively. A metal sheet with thickness $h < d$ is inserted in between the two plates without touching any of them. Then the potential difference between the capacitor plates becomes

A smaller.
B bigger.
C unchanged.

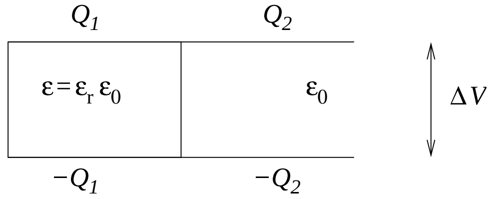


15) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have charge Q and $-Q$, respectively. Which quantity remains unchanged if we increase the distance between the plates?

A The capacitance of the capacitor.
B The electric field between the plates.
C The potential energy stored in the capacitor.
D The potential difference between the plates.

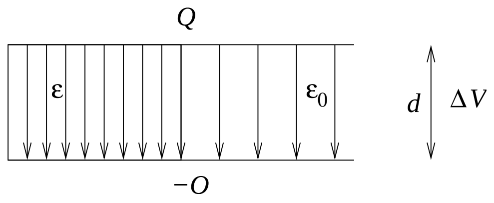
16) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon > \varepsilon_0$ fills the left half of the volume between the capacitor plates, as shown in the figure. In the right half, we have vacuuum. On the left half of the metal plates, we have charge Q_1 and $-Q_1$, respectively, on the right half, we have charge Q_2 and $-Q_2$, respectively. Then,

A $Q_1 = Q_2$
B $Q_1 > Q_2$
C $Q_1 < Q_2$



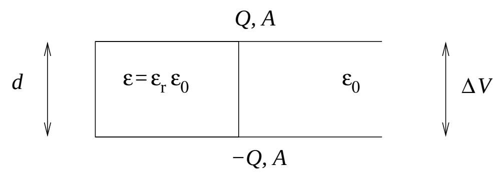
17) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon > \varepsilon_0$ fills the left half of the volume between the capacitor plates, as shown in the figure. In the right half, we have vacuuum. Then the arrows in the figure denote field lines for

A electric displacement $\boldsymbol{D}$
B electric field $\boldsymbol{E}$
C polarization $\boldsymbol{P}$



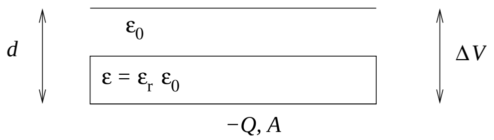
18) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have an area A and charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon = \varepsilon_r \varepsilon_0 > \varepsilon_0$ fills the left half of the volume between the capacitor plates, as shown in the figure. In the right half, we have vacuum. What is the capacitance C, expressed in terms of $C_0 = \varepsilon_0 A/d$, which would have been the capacitance without the dielectric?

A $C = [2\varepsilon_r/(\varepsilon_r + 1)]\, C_0$
B $C = [\varepsilon_r/(\varepsilon_r + 1)]\, C_0$
C $C = \varepsilon_r C_0$
D $C = (\varepsilon_r + 1) C_0$
E $C = [(\varepsilon_r + 1)/2]\, C_0$



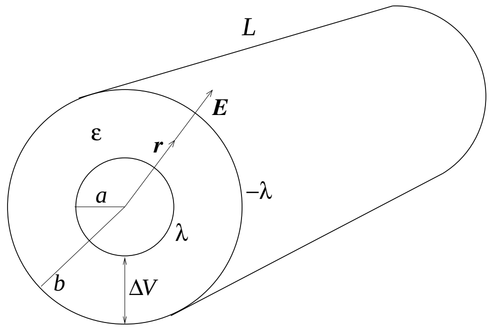
19) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have an area A and charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon = \varepsilon_r \varepsilon_0 > \varepsilon_0$ fills the lower half of the volume between the capacitor plates, as shown in the figure. In the upper half, we have vacuum. What is the capacitance C, expressed in terms of $C_0 = \varepsilon_0 A/d$, which would have been the capacitance without the dielectric?

A $C = [2\varepsilon_r/(\varepsilon_r + 1)]\, C_0$
B $C = [\varepsilon_r/(\varepsilon_r + 1)]\, C_0$
C $C = \varepsilon_r C_0$
D $C = (\varepsilon_r + 1) C_0$
E $C = [(\varepsilon_r + 1)/2]\, C_0$



20) A cylindrical capacitor consists of two (thin) parallel concentric metal cylinders, the inner one with radius a and the outer one with radius b. The two cylinders have length L and charge pr unit length equal to λ (the inner one) and $-\lambda$ (the outer one). A dielectric with permittivity ε fills the volume between the inner and outer metal cylinder. The electric field in the region $a < r < b$ is $\boldsymbol{E}(r) = (\lambda/2\pi\varepsilon r)\hat{r}$, where r denotes the distance from the axis of the cylinders, and $\hat{r}$ is a unit vector directed perpendicularly away from the cylinder axis. What is the capacitance C of this cylindrical capacitor? [Hint: The potential difference between the inner and the outer cylinder is $\Delta V = V_a - V_b = -\int_b^a E(r)\, dr$.]

A $C = \pi\varepsilon L^2/b$
B $C = \pi\varepsilon L^2/a$
C $C = \pi\varepsilon L^3/ab$
D $C = 2\pi\varepsilon L/\ln(a/b)$
E $C = 2\pi\varepsilon L/\ln(b/a)$



Øving 8 i Elektromagnetisme / Elektrisitet og magnetisme våren 2004

To be delivered by: Thursday March 4 kl. 1200.

Navn:

Øvingsgruppe:

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