Institutt for fysikk, NTNU
TFY4155/FY1003: Elektrisitet og magnetisme
Vår 2005

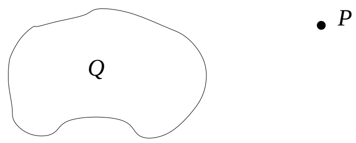
Øving 9

Guidance: 01.03, 02.03, 03.03, 04.03, 08.03, 09.03, 10.03
(In auditorium, not in the small rooms. See guidance plan on the home page.)
To be delivered by: Monday March 14 at 12 noon. (Table for your answers on last page.)

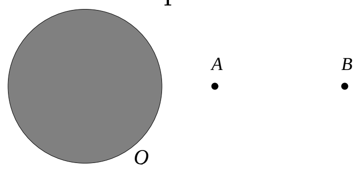
Information:

- 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).

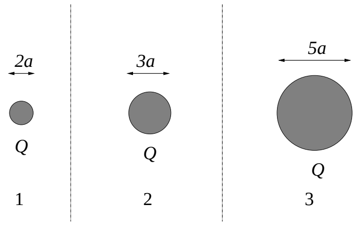
1) An arbitrarily shaped conductor has net charge Q. What happens in the point P if the charge on the conductor is increased to $2Q$?
A Only the potential is doubled.
B Only the electric field strength is doubled.
C Both the potential and the electric field strength are doubled.
D Both the potential 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 $E_A = 2E_B$, $V_A = 4V_B$
D $E_A = 2E_B$, $V_A = 2V_B$

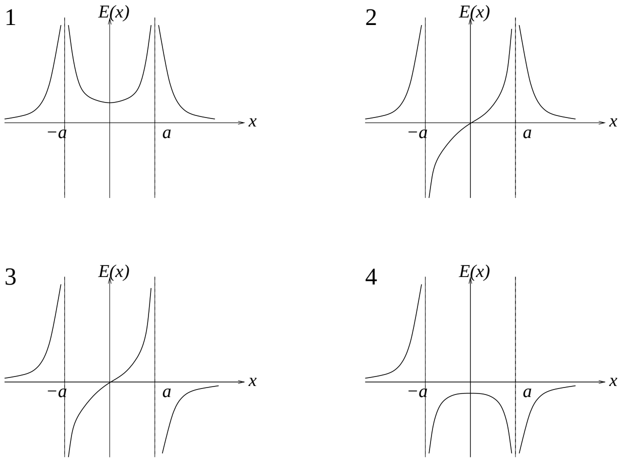


3) Three isolated metal spheres 1, 2, and 3 (i.e., they do not influence *each other*) each have a positive charge Q. The diameter of the spheres is $2a$, $3a$, and $5a$, respectively. How is the potential on the three spheres related to each other?



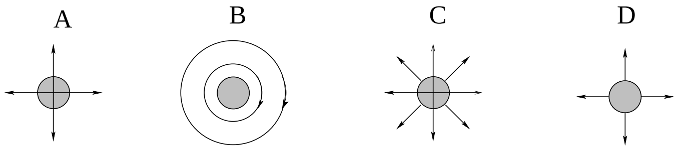
A $V_1 : V_2 : V_3 = 2 : 3 : 5$
B $V_1 : V_2 : V_3 = 5 : 3 : 2$
C $V_1 : V_2 : V_3 = 6 : 10 : 15$
D $V_1 : V_2 : V_3 = 15 : 10 : 6$

4) Two negative point charges, each with charge $-q$, are located on the x axis, in $x = a$ and in $x = -a$, respectively. The electric field on the x axis is then $\boldsymbol{E}(x) = E(x)\,\hat{x}$. Which graph shows the correct $E(x)$?



A 1
B 2
C 3
D 4

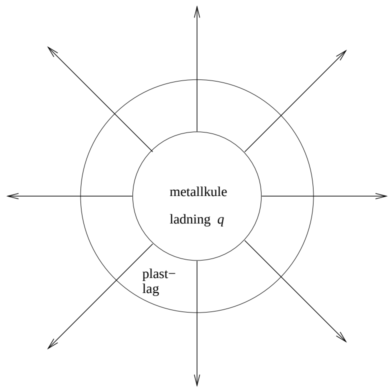
5) The correct figure shows electric field lines in a plane passing through the center of a metal sphere with net charge $Q > 0$.



A
B
C
D

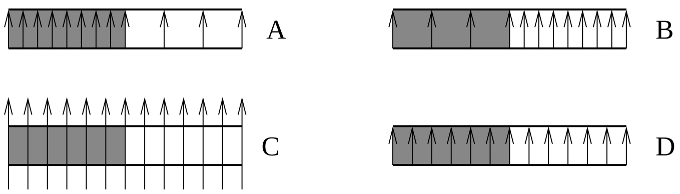
6) A metal sphere with charge q and radius R is covered with a layer of electrically neutral plastic with thickness R and permittivity $\varepsilon = 3\varepsilon_0$. The arrows in the figure than illustrate field lines for

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



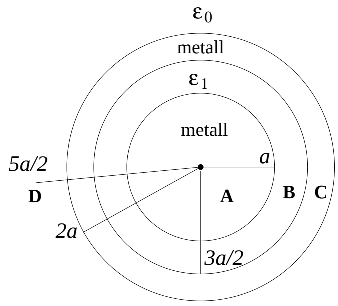
7) The correct figure shows electric field lines for a parallel plate capacitor that is half filled with a dielectric (i.e., the hatched region has $\varepsilon > \varepsilon_0$). The linear dimension of the plates is large compared to the distance between the plates. The upper plate has negative charge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

A
B
C
D

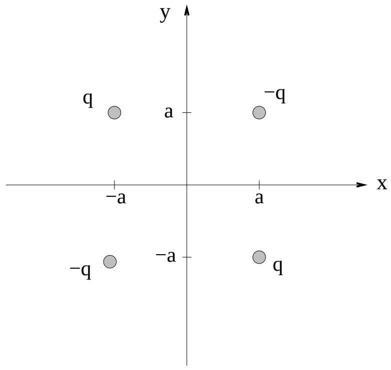


8) A compact metal sphere with radius a has a net charge $q > 0$. It is covered with a layer of (electrically neutral) plastic with thickness $a/2$. Outside follows an (electrically neutral) metallic spherical shell of thickness $a/2$. Outside this, we have vacuum. The plastic is a dielectric with permittivity $\varepsilon_1 = 10\varepsilon_0$. 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



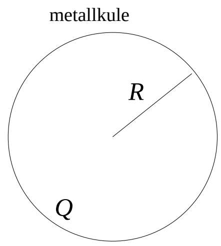
9) Four point charges lie in the xy plane. Two have positive charge q and lie in $(x, y) = (a, -a)$ and $(-a, a)$. The two others have negative charge $-q$ and lie in $(x, y) = (a, a)$ and $(-a, -a)$. What is the direction of the electric field $\boldsymbol{E}$ on the x axis (assume $x > a$), i.e., in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



A Along $\hat{x}$.
B Along $-\hat{x}$.
C Along $\hat{y}$.
D Along $-\hat{y}$.

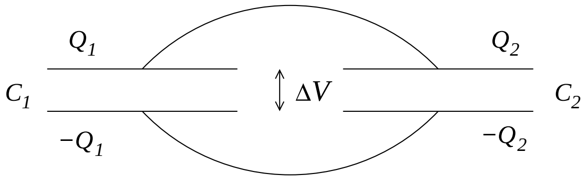
10) For the four point charges shown in nr 9 above: What is $V(x, 0)$, i.e., on the x axis?
A $V = 0$
B $V = q/4\pi\varepsilon_0 x$
C $V = q/4\pi\varepsilon_0\sqrt{(x-a)^2 + a^2}$
D $V = -q/4\pi\varepsilon_0\sqrt{(x-a)^2 + a^2}$

11) A metal sphere of radius R has 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 $U = Q^2/2\pi\varepsilon_0 R$
C $U = Q^2/4\pi\varepsilon_0 R$
D $U = Q^2/8\pi\varepsilon_0 R$

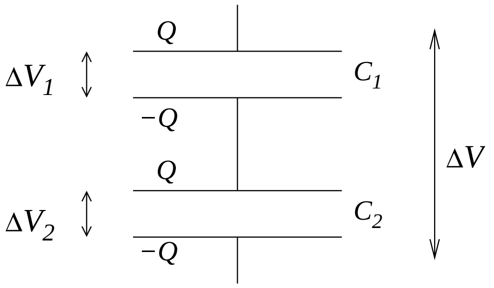
12) Two parallel plate capacitors are connected in *parallel*, as shown in the figure. The upper metal plates are connected via an electric conductor (e.g. a copper wire) so that these two plates have the same electric potential. The same applies to the two lower metal plates. Therefore, the potential 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 $(C_1 + C_2)/2$
C $(1/C_1 + 1/C_2)^{-1}$
D $2(1/C_1 + 1/C_2)^{-1}$

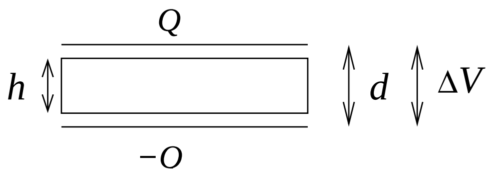
13) Two parallel plate capacitors are connected in *series*, as shown in the figure. The lower metal plate of capacitor 1 is connected to the upper metal plate of capacitor 2 via a conductor (e.g. a copper wire) so that these two plates have the same electric potential. The total potential difference (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 $(C_1 + C_2)/2$
C $(1/C_1 + 1/C_2)^{-1}$
D $2(1/C_1 + 1/C_2)^{-1}$



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 slab with thickness $h = 2d/3$ is inserted mid between the two plates. Then the potential difference between the capacitor plates becomes

A nine times larger.
B three times larger.
C three times smaller.
D nine times smaller.

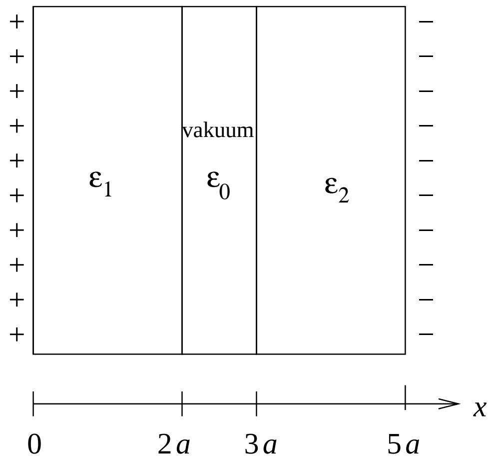


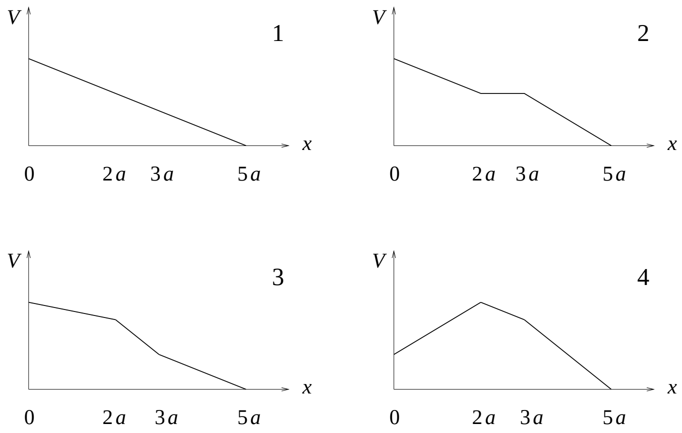
15) The potential on an infinitely large positively charged plane is -20 V. The plane has a uniform charge density 4 nC/m^2. In what distance from the plane is then $V = 0$?

A 9 m
B 9 cm
C 9 mm
D The potential V is here everywhere negative.

16) Two approximately infinitely large metal plates have charge $\pm\sigma$ pr unit area and are located in the yz plane, i.e., in $x = 0$ (the positive plate) and in $x = 5a$ (the negative plate), as shown in the figure. The region between the plates is partly filled with two (electrically neutral) dielectric layers, as shown in the figure. The dielectric layer in the region $0 < x < 2a$ has permittivity $\varepsilon_1 = 4\varepsilon_0$. The dielectric layer in the region $3a < x < 5a$ has permittivity $\varepsilon_2 = 2\varepsilon_0$. Which of the four given graphs in the figure to the right then illustrates the potential V as a function of the distance x from the positively charged metal plate?

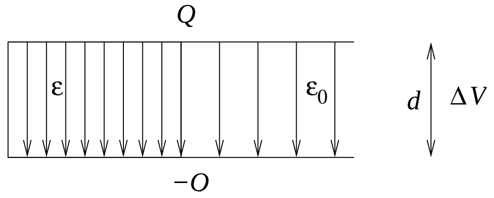
A 1 B 2 C 3 D 4





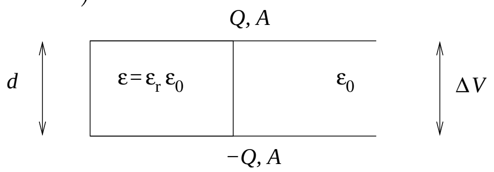
17) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon > \varepsilon_0$ fills the left half of the volume between the capacitor plates, as shown in the figure.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

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



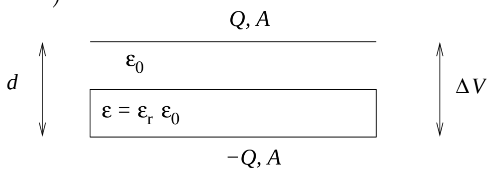
18) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have an area A and charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon = \varepsilon_r\varepsilon_0 > \varepsilon_0$ fills the left half of the volume between the 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? (Hint: This is essentially two capacitors connected in parallel.)

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



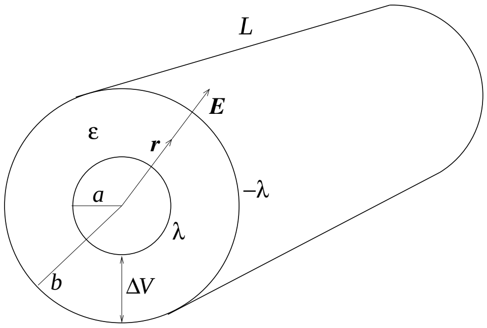
19) A parallel plate capacitor is made of two parallel metal plates separated by a distance d. The two metal plates have an area A and charge Q and $-Q$, respectively. A dielectric with permittivity $\varepsilon = \varepsilon_r \varepsilon_0 > \varepsilon_0$ fills the lower half of the volume between 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? (Hint: This is essentially two capacitors connected in series.)

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



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: First, find the potential difference ΔV between the inner and the outer cylinder.]

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



Øving 9 i Elektromagnetisme / Elektrisitet og magnetisme våren 2005

To be delivered by: Monday March 14 at noon.

Name:

Group:

Exercise	A	B	C	D
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It is sufficient to deliver this table, filled in with your answers, before the deadline in order to get this one approved.