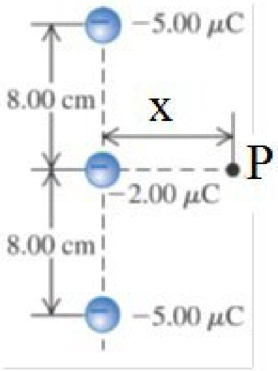
Waves and electromagnetism Sheet 1 Course 2023-24

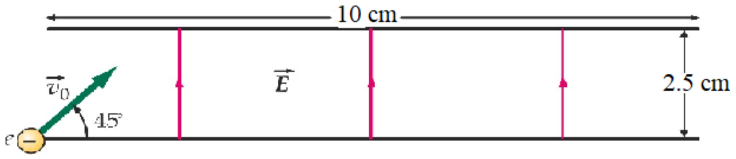
1. Electric charges of +125 μC have been placed at three vertices of a square of side 0.4 m. Calculate: a) The electric field at the fourth vertex. b) Calculate the force exerted by the three charges on an electron located in the fourth vertex

2. Let three negative point charges be aligned as shown in the figure. Calculate the magnitude and direction of the electric field created by these point charges at point P, located at x = 7 cm from the charge of -2μC.



3. Two equal positive charges of value $q_1 = q_2 = 6$ nC are on the y-axis at points $y_1 = 3$ cm and $y_2 = -3$ cm. a) What is the value and direction of the electric field on the x-axis at x = 4 cm? b) What is the force exerted on a third charge $q_0 = 2$ nC located at x = 4 cm?

4. An electron starts from the position shown in the figure, with an initial speed of 5×10^6 m/s, forming an angle of 45° with the horizontal, in a region with an electric field $\vec{E} = 3.5\times10^3\,\vec{j}$ N/C. If gravity is neglected, determine on which plate and in which place the electron will collide?



5. a) Two charges of 24 μC and -7 μCare inside a spherical shell of radius 25 cm. What is the total electric flux through the shell? b) Repeat if the same charges are inside a cube of side 25 cm.

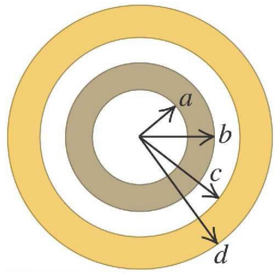
6. An insulating solid sphere of radius 17 cm has a charge of 8 μC uniformly distributed throughout its volume. Calculate the charge enclosed by a concentric spherical surface (with the sphere) with the following radii: a) r = 5 m; b) r = 24 cm. Calculate also the electric field for the same radii.

7. A spherical crust of radius R_1 has a total charge q_1 uniformly distributed on its surface. A second larger spherical crust of radius R_2, concentric with the previous one, has a charge q_2 uniformly distributed on its surface. (a) Use Gauss's law to find the electric field in the regions $r<R_1$, $R_1<r<R_2$ and $r>R_2$.

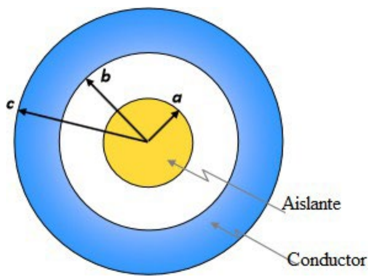
8. A very long straight wire has a linear charge density λ = 6 μC/m. Determine the electric field strength at the following distances from the wire: a) r = 5 cm, b) r= 30 cm.

9. A sphere of radius 6 cm has a uniform volume charge density ρ =450 nC/m^3. (a) What is the total charge of the sphere? Determine the electric field at (b) r = 2 cm, (c) r = 5.9 cm, (d) r = 6.1 cm.

10. A small conducting spherical shell of inner radius *a* and outer radius *b* is concentric with another large spherical shell of inner radius *c* and outer radius *d*. The inner shell has a total charge -2q and the outer shell has an outer charge +6q. a) Calculate the total charge using Gauss's law on (i) inner surface of the small shell, (ii) outer surface of the small shell, (iii) inner surface of the large shell, (iv) outer surface of the large shell. b) Calculate the electric field (magnitude and direction) as a function of q and the distance r from the common center of the two shells for: (i) r<*a*; (ii) *a*<r<*b*; (iii) *b*<r<*c*; (iv) *c*<r<*d*; (v) r>*d*.

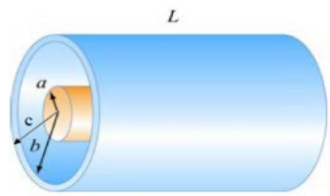


11. In the figure, two concentric spheres are represented, one insulating, solid, of radius *a* = 2 cm and with a volumetric charge density ρ =4.50×10^{-6} C/ m^3, and the other conductive, hollow, of internal radius *b* = 5 cm and external radius *c* = 8 cm and with a charge Q = 2 nC. a) Determine the enclosed charge and the electric field at r = 1cm, r = 3cm, r = 7 cm and r = 10 cm. b) Determine the potential difference of the conducting crust.



12. A solid insulating cylinder of radius *a* has a charge +2Q uniformly distributed throughout its volume. Surrounding the insulating cylinder is a conducting cylindrical shell (cortex) of net charge -3Q with inner radius *b* and outer radius *c*. Calculate:

a) The enclosed charge for r = *a*/2 and the electric field vector for r = *a*/2.
b) The enclosed charge and the electric field vector for *a* < r < *b*
c) The enclosed charge and the electric field vector for *b* < r < *c*
d) The enclosed charge and electric field vector for r > *c*.
e) Charge on the inner and outer surfaces of the conducting cortex.



13. A non-conducting solid sphere of radius *R* has a charge density $\rho = \rho_0 \left(\frac{r}{R}\right)$, with ρ0 a constant:

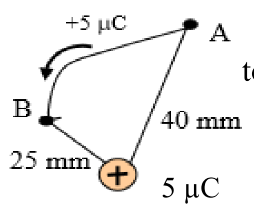
a) Show that the total charge is $Q = \pi R^3 \rho_0$

b) Show that the total charge inside a sphere of radius r < R is $q = Q\left(\frac{r^4}{R^4}\right)$.

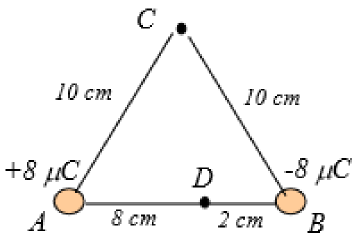
c) Use Gauss's law to calculate the electric field vector $\vec{E}$ at any point.

d) Calculate the potential V at any point assuming V(∞)= 0.

14. Points A and B are located 40 mm and 25 mm respectively from the +6 µC charge. Calculate the work required to move the 5 µC charge from point A to point B.

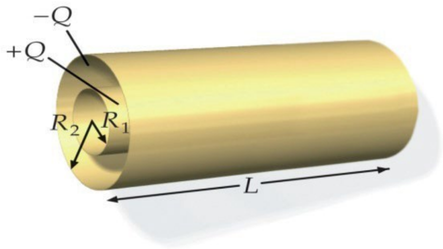


15. Points A, B and C are the corners of an equilateral triangle of side 10 cm. At points A and B there are two charges +8 μC and -8 μC respectively. Calculate: a) The potential at point C due to the two charges, b) The potential at point D due to the two charges, c) Calculate the work needed to move a charge of 2 μC from point C to point D.



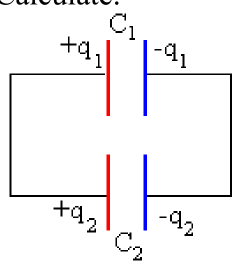
16. A plane-parallel sheet capacitor consists of two square conducting plates of side 8 cm. The plates are initially 4 mm apart. The capacitor is connected to a 16 V battery. Calculate the capacitance, charge of each plate and electric field. If the plates are separated up to 7.5 mm, calculate the new capacity, the new charge on each plate and the new electric field if the process is done: a) disconnecting the battery; b) keeping the battery connected.

17. Consider a cylindrical capacitor of length L =50 cm consisting of two cylindrical conducting shells. The inner crust has a radius $R_1 = 2$ cm and a charge $+Q = 10^{-9}$ C; the outer crust has a radius $R_2 = 4$ cm and a charge $+Q = -10^{-9}$ C. ($\varepsilon_0 = 8.85\times10^{-12}$ F/m). Calculate: a) Electric field of the capacitor at any point as a function of r ($r<R_1$, $R_1<r<R_2$, $r>R_2$); b) Electric potential between the capacitor crusts; c) Capacitance of the capacitor.

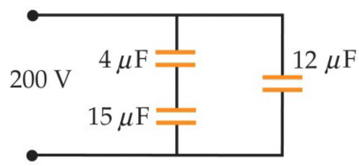


18. Suppose two identical capacitors connected in parallel and charged to a potential difference of 100V. After charge, they are isolated from the battery. Then a dielectric ($\varepsilon_r = 3$) is introduced into one of the two capacitors, which completely fills the space between the plates. Calculate:

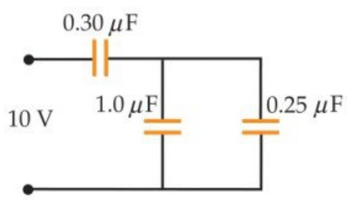
a) the charge of each capacitor before and after introducing the dielectric.
b) the potential difference after introducing the dielectric.
c) the energy of each capacitor before and after introducing each dielectric.



19. Calculate for the device shown in the figure: a) Total effective capacitance between terminals. b) Charge stored in each capacitor. c) Total energy stored.



20. Calculate for the device shown: a) the total effective capacitance between the terminals. b) the charge stored in each of the capacitors and c) the total energy stored.



21. Two capacitors of capacitance $C_1 = 4$ μF and $C_2 = 12$ μF are connected in series and powered by a 12 V battery. They are carefully disconnected from the battery without discharging and are now connected in parallel by joining their positive and negative sides: a) Calculate the potential difference across each of the capacitors after they are connected. b) find the initial and final energy stored in the capacitors.

22. Two identical flat capacitors of 10 μF capacity are connected in parallel and charged by an electromotive force of 100 V, after which they are isolated from the battery. One of the capacitors is then filled with a dielectric of dielectric constant 3, occupying the entire space between plates. Calculate: (a) The charge of each capacitor and the total charge before and after introducing the dielectric. (b) The potential difference between plates after introducing the dielectric. (c) The energy of each capacitor before and after introducing the dielectric.

23. Two identical capacitors, of parallel plates and capacitance 4 μF each, are connected in series across a 24 V battery. a) what is the charge on each capacitor? What is the voltage across each capacitor? A dielectric of constant 4.2 is inserted between the plates of one of the capacitors while the battery is still connected. b) Once the dielectric is inserted, what is the charge on each capacitor? What is the difference across each capacitor?

24. A 1.2 μF capacitor is charged to 30 V. After charging, it is disconnected from the voltage source and connected to another discharged capacitor. The final voltage is 10 V. a) What is the capacitance of the second capacitor? b) How much energy was lost in making the connection?