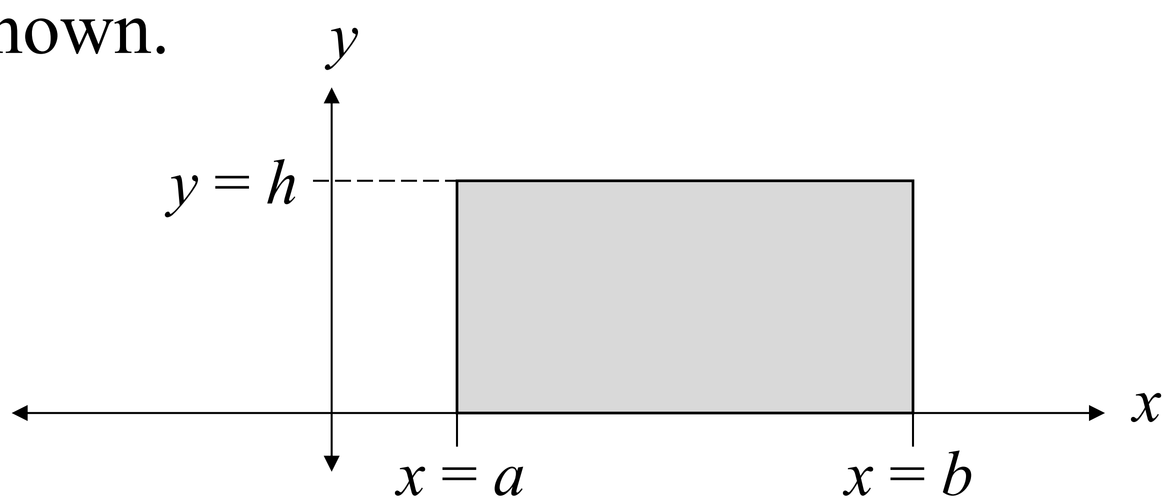
1. There is a uniform electric field for regions near the surface of the earth equal to –150 N/C $\hat{k}$. (It is directed toward the center of the earth or simply "downward".) Determine the electric flux for each of the following: (a) the foor of the room, dimensions = 9.0 m × 14 m, (b) a wall of the room, dimensions = 14 m × 3.0 m, (c) a book cover of dimensions 9.0 cm × 14 cm that is tilted open at a 45° angle as the book rests on a table, and (d) a sheet stretched tight with each corner attached to one of the four corners of the room (at any height) such that the edges of the sheet abut the walls of the room.

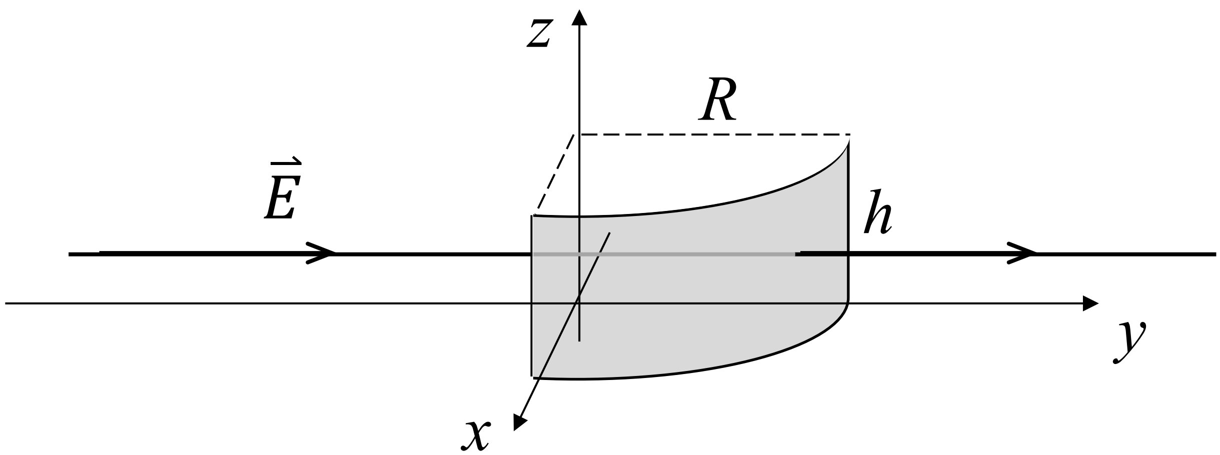
2. Supposing the earth's electric field "obeys" an "inverse square law", determine the electric flux for the same floor as above located at an altitude 0.414 times the radius of the earth (with its surface level).

3. A shoe box of dimensions 30.0 cm × 15.0 cm × 10.0 cm is tilted with one of its edges touching the floor. Determine the net electric flux for the box and show that it does not depend upon the angle at which it is tilted. Note: the net electric flux is the sum of the flux values for all six sides of the box.

4. An electric field of variable strength is described by: $\vec{E} = cx^3\hat{k}$ within a certain volume of space. Derive an expression for the electric flux of the rectangular region shown.

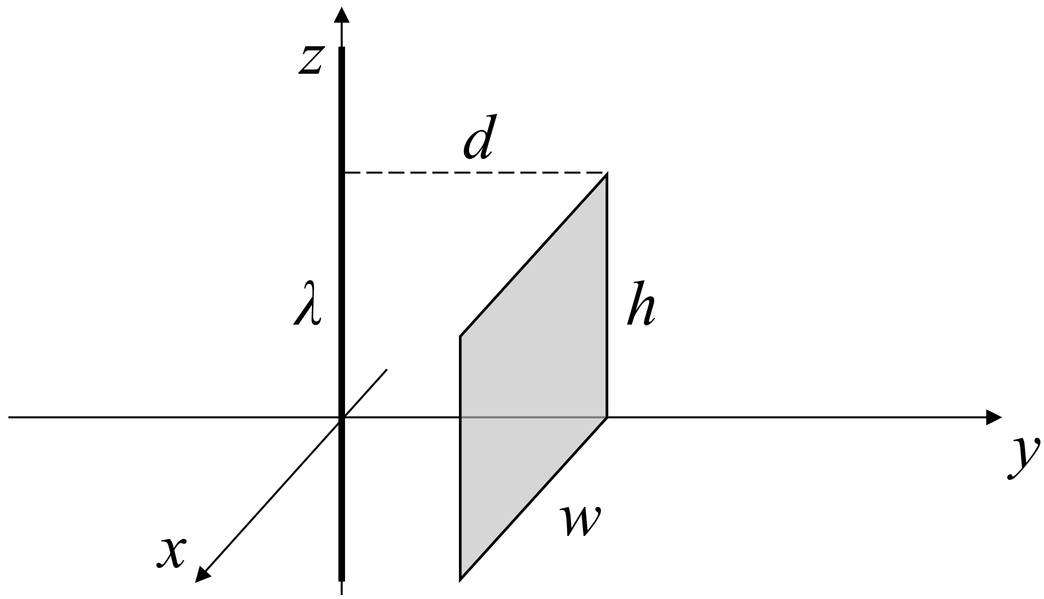


5. A "quarter-cylinder" of height h and radius R is centered on the z-axis and located in the first quadrant. Determine the electric flux for a uniform field, $E\,\hat{\imath}$, through the surface.

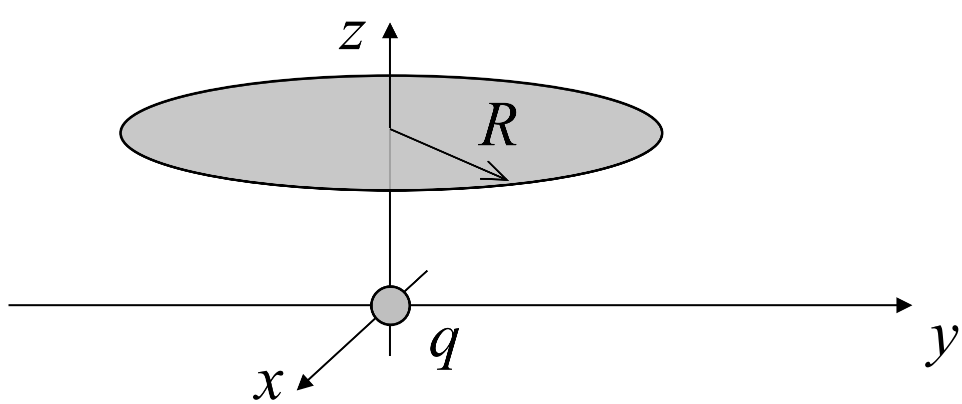


6. Determine the electric flux for a cylindrical surface of length L and radius R centered along an infinite line of charge with charge per length = λ.
(The field is given by: $\vec{E} = \frac{\lambda}{2\pi\varepsilon_0 r}\hat{r}$)

7. A line of charge λ is located all along the z-axis. Determine the electric flux for a rectangular surface with coordinates (0, d, 0), (0, d, h), (w, d, 0), (w, d, $\underline{h}$).



8. A point charge q is located at the origin. A disk of radius R that is parallel to the x-y plane is located with its center at (0, 0, z). Determine the electric flux for the disk.



9. A point charge q is located at the origin. Determine the electric flux for a spherical surface of radius R is centered on the origin.

10. A point charge 5.0 nC is located at the precise center of a regular dodecahedron. The length of each edge is 10.0 m. The area of each face is 172 m^2. Radii of circumscribed and inscribed spheres are 14.0 m and 11.1 m (a) Use Gauss's Law to determine the flux through one of the faces. (b) Estimate the flux with Coulomb's Law.

11. A point charge of −3.0 nC is located at the precise center of a tetrahedron. A second point charge +2.0 nC is located at the precise center of a second tetrahedron that shares a face with the first. (a) Find the flux through the shared face. (b) Determine the flux for the other faces.

12. A metal sphere of radius R has charge Q. Determine the electric field inside and outside the sphere. Sketch a graph of field strength vs. radial distance.

13. A nonconducting sphere of radius R has a charge Q distributed uniformly through its volume. Determine the electric field as a function of r for points inside and outside.

14. Use Gauss's Law to determine the electric field of an infinite line of charge λ.

15. A cylinder of radius R and infinite length has a uniform charge density ρ. Determine the electric field.

16. Use Gauss's Law to determine the electric field very near of a sheet of charge σ.

17. A conducting plate has a uniform charge per area σ distributed along its surface. Determine the electric field inside the plate and immediately outside the plate.

18. A point charge of +3.0 nC is surrounded by a spherical uniform surface charge of –4.0 nC with radius 20.0 cm. Determine the electric field at $r = 10.0$ cm and $r = 30.0$ cm. Repeat for a case where the spherical charge is –3.0 nC instead of –4.0 nC.

19. An infinitely wide and long nonconducting plate has a uniform charge density ρ. Determine the electric field.

20. A nonconducting sphere has a *nonuniform* charge per volume given by: $\rho = ar + b$, where a and b are constants. Determine the electric field.

21. What would be Gauss's Law for gravitation? Use this result and the previous problem to determine an equation for g that applies to the earth's interior. Determine the values of a and b given that the density at the center of the earth is estimated to be 12000 kg/m^3.

22. Two point charges are separated by $2\underline{0}$ cm. The charges have values: $q_1 = -2.0$ nC and $q_2 = -3.0$ nC. (a) Determine the potential energy relative to infinity. (b) Determine the amount of work necessary to move q_2 closer so that it is only 15 cm away from q_1.

23. A point charge $q_1 = -6.0$ nC is separated by 5.0 cm from another point charge, $q_2 = +1.0$ nC. Determine the amount of work necessary: (a) to separate the two charges to a infinite distance. (b) to separate the two charges to a distance of 5.0 m.

24. Determine the amount of work necessary to assemble three point charges, each with charge $\pm q$, into an equilateral triangle of side L for two cases: all the same sign and one the opposite sign of the other two.

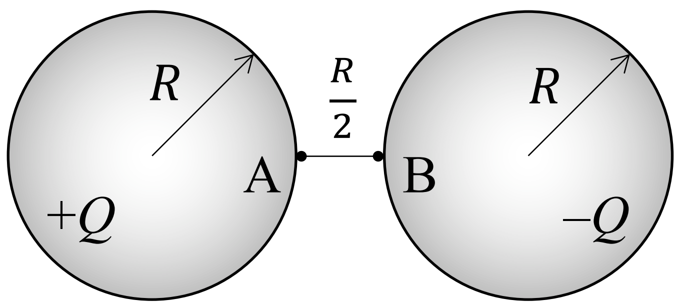
25. Two deuterium nuclei with opposite velocities in the core of the Sun "collide". In order for fusion to occur the nuclei must be separated by less than 5.0×10^{-15} m. What must be the speed of each in order for fusion to occur? Each nucleus has mass 3.34×10^{-27} kg and charge 1.60×10^{-19} C.

26. In the simple Bohr model of the hydrogen atom, an electron moves in a circular orbit of radius r around a fixed proton. (a) What is the potential energy of the electron? (b) What is the kinetic energy of the electron? (c) Calculate the total energy when it is in its ground state with an orbital radius of $r = 5.30 \times 10^{-11}$ m. (d) How much energy is required to ionize the atom from its ground state?

27. A pith ball of mass 0.10 grams is brought near a charged sphere of radius 15 cm and charge −2.0 μC. The pith ball touches the sphere and acquires a charge of −1.0 nC and quickly darts away. Ignoring gravity estimate the speed of the pith ball at a distance of 5 cm from the surface of the sphere.

28. (a) Determine the electric potential at distances 1.0 cm, 2.0 cm, and 3.0 cm from a point charge of 5.0 nC. (b) Determine the potential energy of a 10.0 nC charge located 3.0 cm from the 5.0 nC charge.

29. Two spheres of radius R have charges $\pm Q$. The surfaces are separated by distance $R/2$.



(a) Determine the difference in potential, $V_B - V_A$ just above surfaces of the spheres. (b) Determine the kinetic energy gained by an electron that traverses the gap between the spheres. (c) Calculate the speed attained, given $Q = 2.0\ \mu C$, $R = 0.13$ m

30. A point charge of $+q$ is located at the origin and a charge of $-2q$ is at coordinates $(a, 0)$.
   (a) Find the potential at each point: $(a/2, 0)$, $(a/4, 0)$, $(0, a)$.
   (b) Determine the point(s) where $V = 0$.
   (c) Determine the point(s) where $\mathbf{E} = 0$.
   (d) Sketch the electric field and equipotential lines.

31. A charge Q is uniformly distributed in a ring of radius R centered on the origin and located in the xy plane. Determine the potential for an arbitrary point along the z-axis.

32. Repeat the previous problem but with a disk of charge instead of a ring of charge.

33. Determine the potential difference from a distance of 1.0 cm to a distance of 3.0 cm from a point charge of – 5.0 nC. (Hint: Use the results from one of the previous problems.)

34. (a) Given the electric field of the earth: –150 N/C $\hat{k}$, determine the potential difference from the floor to the ceiling, a distance of 3.0 m. (b) As a positive charge moves from the floor to the ceiling does it gain or lose potential energy? (c) As a positive charge moves from the floor to the ceiling does the electric field do positive or negative work? (d) How about a negative charge?

35. The electric field of an infinite line of charge is given by $\vec{E} = \frac{\lambda}{2\pi\epsilon_0 r}\hat{r}$. Use this to estimate the potential difference from 0.5 cm to 1.5 cm away from the center of a plastic rod of length 20.0 cm and charge +6.0 nC.

36. Determine the electric potential as a function of distance from the center of a hollow spherical shell of radius R and uniform charge Q.

37. A charge Q distributed throughout the volume of a nonconducting sphere of radius R such that the field within is given by: $\vec{E} = \frac{Qr^2}{4\pi\epsilon_0 R^4}\hat{r}$, $r < R$. Determine the electric potential at the precise center of the sphere.

38. A proton initially at the origin with velocity 3.0 Mm/s $\hat{\imath}$ encounters a region with electric potential described by $V = 12000 + 5000x$ (units of volts and meters). (a) Sketch field and equipotentials. (b) Determine the electric field. (c) Determine kinetic energy, velocity, and acceleration of the proton as it reaches $x = 5.0$ m. (d) How far will the proton "penetrate" this region?

39. Two parallel aluminum square plates (10.2 cm on a side) are separated by 2.0 mm and connected to a 6.0 V battery. (a) Sketch the electric field and equipotential lines. (b) Determine the electric field between the plates. (c) Determine the charge density on each plate. (d) Determine the amount of charge on each plate. (e) Repeat these steps for the same plates separated by 6.0 mm.

40. Suppose a CRT requires electrons to be accelerated from rest to 7.0×10^7 m/s. This acceleration occurs between two parallel plates separated by 0.50 cm. (a) Determine the required voltage difference across the plates. (b) Determine the electric field between the plates. (c) Determine the surface charge density on each plate.

41. Use the result from problem #29 to determine the electric field along the axis of a ring of charge.

42. The electric potential in a certain region is given by $V = 3xy$. Determine algebraic expressions for the components of the electric field in the same region. Sketch the electric field and equipotential lines.

43. A metallic disk of radius 2.8 cm is at potential $3\underline{0}00$ V. (a) Determine the net charge on the disk. (b) Determine the potential energy of the charged disk.

44. A second identical metallic disk is arranged parallel to the disk in the previous problem, separated by a distance 0.82 cm. A power supply maintains a potential difference of $3\underline{0}00$ V. (a) Determine the charge on each disk. (b) Determine the electric field at a point midway between the disks.

45. The Van de Graaff generator has a sphere of diameter 23 cm and a charge of $-2.0\ \mu C$. (a) Determine the electric potential at its surface. (b) Determine the amount of work that must be done to produce that charge on the sphere. (c) Determine the maximum charge and electric potential that would be possible with a sphere of this diameter given the dielectric strength of the air is 3.0×10^6 V/m.

46. Now suppose you consider that the negative charge placed on the sphere of the generator is being transferred not "from infinity" but from a nearby sphere of equal size (and, eventually, equal but opposite charge). Discuss qualitatively how the results of the previous problem would be different.

47. The 30.0 cm diameter metal sphere atop a Van de Graaff generator is connected by a long wire to a second metal sphere of diameter 10.0 cm. If the larger sphere obtains net charge +3.0 μC, what is the charge on the smaller sphere? Find the charge per area for each sphere.

48. An "infinite" metal pipe with zero net charge has inner radius a and outer radius b. An "infinite" line of charge λ is inserted along the axis of the pipe.
    (a) Find the surface charge densities for the inner and outer surfaces of the pipe.
    (b) Determine the electric field for regions inside, within, and outside the pipe.
    (c) Determine the potential difference from $r = a/2$ to $r = 2b$.
    (d) Determine the electric potential of the inside surface of the pipe.

49. A uniformly charged nonconducting sphere of radius 10.0 cm and charge –2.0 μC is surrounded by a conducting shell of inner radius 55.0 cm, outer radius 60.0 cm, and charge +3.0 μC. Determine the potential difference of the shell relative to the sphere. Determine the potential at the center of the sphere (relative to infinity).

Answers

1. a. −19000 N m^2/C
   b. 0
   c. −1.3 N m^2/C
   d. −19000 N m^2/C
2. −4700 N m^2/C
3. 0
4. $\dfrac{cw\left(b^4 - a^4\right)}{4}$
5. ELR
6. $\dfrac{\lambda L}{\varepsilon_o}$
7. $\dfrac{\lambda L}{2\pi\varepsilon_o}\tan^{-1}\left(\dfrac{w}{R}\right)$
8. $\dfrac{zq}{2\varepsilon_o}\left(\dfrac{1}{z} - \dfrac{1}{\sqrt{R^2 + z^2}}\right)$
9. $\dfrac{q}{\varepsilon_o}$
10. a.
    b.
11. a.
    b.
12. $\mathbf{E} = \dfrac{Qr}{4\pi\varepsilon_o R^3}\hat{\mathbf{r}}, \quad r \le R$

    $\mathbf{E} = \dfrac{Q}{4\pi\varepsilon_o r^2}\hat{\mathbf{r}}, \quad r \ge R$
13. $\mathbf{E} = \dfrac{\lambda}{2\pi\varepsilon_o r}\hat{\mathbf{r}}$
14. $\mathbf{E} = \dfrac{\rho r}{2\varepsilon_o}\hat{\mathbf{r}}, \quad r \le R$

    $\mathbf{E} = \dfrac{\rho R^2}{2\varepsilon_o r}\hat{\mathbf{r}}, \quad r \ge R$
15. $E = \dfrac{\sigma}{2\varepsilon_o}$, perpendicular to surface
16. $E = \dfrac{\sigma}{\varepsilon_o}$, perpendicular to surface
17. a. 2700 N/C away from center; 100 N/C toward center
    b. 2700 N/C away from center; 0
18. $E = \dfrac{\rho w}{2\varepsilon_o}$, perpendicular to surface for all points outside the slab

    $E = \dfrac{\rho y}{\varepsilon_o}$, perpendicular to surface for all points inside the slab

19. $\mathbf{E} = \frac{ar^2}{4\varepsilon_o} + \frac{br}{3\varepsilon_o}\hat{\mathbf{r}}, \quad r \le R$

$\mathbf{E} = \left(\frac{aR^4}{4\varepsilon_o} + \frac{bR^3}{3\varepsilon_o}\right)\frac{1}{r^2}\hat{\mathbf{r}}, \quad r \ge R$

20. $\oint \mathbf{g} \cdot d\mathbf{A} = -4\pi G M_{enc}$

$\mathbf{g} = -4\pi G\left(\frac{ar^2}{4} + \frac{br}{3}\right)\hat{\mathbf{r}}, \quad r \le R$

$a = -1.36 \times 10^{-3}$ kg/m^4 and $b = 12000$ kg/m^3

21. a. 2.7×10^{-7} J
    b. 9.0×10^{-8} J
22. a. 1.1×10^{-6} J
    b. 1.1×10^{-6} J
23. $\Sigma W = -\frac{kq^2}{a}$
24. 3.7×10^6 m/s
25. a. $U = -\frac{ke^2}{r}$
    b. $K = \frac{ke^2}{2r}$
    c. -2.18×10^{-18} J
    d. 2.18×10^{-18} J (13.6 eV as expected)
26. 0.77 m/s
27. a. 4500 V, 2250 V, 1500 V
    b. 15 μJ
28. a. $V = -\frac{2kq}{a}$
    b. $V = \frac{4kq}{3a}$
    c. $V = \frac{(1-\sqrt{2})kq}{a}$
    d. $V = 0$ for all points that satisfy: $3x^2 + 2ax + 3y^2 = a^2$
    (This is a circle of radius $2a/3$ centered on $(-a/3, 0)$
    e.
29. $V = \frac{kQ}{\sqrt{z^2 + R^2}}$
30. $V = \frac{Q}{2\pi\varepsilon_o R^2}\left(\sqrt{R^2 + z^2} - z\right)$
31. 3000 V
32. a. 450 V
    b. gain
    c. negative
    d. lose; positive
33. 590 V
34. a. $v = 2.0$ Mm/s $\mathbf{i}$
    b. 9.4 m

c. −5000 V/m **i**
d. 93.7 Mm/s
35. a.
b. 3000 V/m
c. 2.66×10^{-8} C/m^2
d. 0.28 nC
e. 1000 V/m, 8.85×10^{-9} C/m^2, 0.092 nC
36. a. 13.9 kV
b. 279 kN/C
c. 2.47×10^{-6} C/m^2
37. $\mathbf{E} = \dfrac{Qz}{4\pi\varepsilon_o\left(z^2 + R^2\right)^{\frac{3}{2}}}\hat{\mathbf{k}}$
38. $\mathbf{E} = -3y\,\mathbf{i} - 3x\,\mathbf{j}$
39. a. −156 kV
b. 0.156 J
c. 4.4 μC
40.
41.
42. a. 4.67 nC
b. 7.01 μJ
43. a. 9.31 nC
b. 307 kN/C
(estimates assuming field is uniform: 7.98 nC, 366 kN/C)
44.
45.
46.
47. a. $\sigma_a = -\dfrac{\lambda}{2\pi a}$, $\sigma_b = \dfrac{\lambda}{2\pi b}$
b. $\mathbf{E} = \dfrac{\lambda}{2\pi\varepsilon_o r}\hat{\mathbf{r}}, \quad r < a, r > b$
$\mathbf{E} = 0, \quad a < r < b$
c.
48. a. +147 kV
b. −132 kV