13. (II) A point charge Q is at the origin. Show that the components of the electric field at a distance r are given by

$$E_\alpha = \frac{kQ\alpha}{r^3}$$

where $\alpha = x, y,$ or z. (*Hint:* Note that $\mathbf{E} = E_x\mathbf{i} + E_y\mathbf{j} + E_z\mathbf{k} = (kQ/r^3)\mathbf{r}$. Use the dot product.)

4. (I) A uniformly charged rod with a linear charge density λ C/m is in the form of a circular arc of radius R, as shown in Fig. 23.49. (a) What is the field strength at the center? (b) Show that the field strength at the center of a uniformly charged semicircular rod is $2k\lambda/R$.

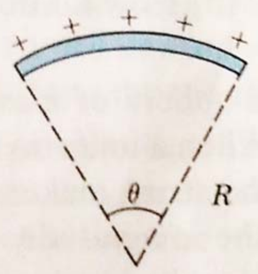


FIGURE 23.48 Problem 4.

7. (II) Show that the field strength at a distance y along the perpendicular bisector of a uniformly charged rod of length L, as in Fig. 23.50 is given by

$$E = \frac{2kQ}{y(L^2 + 4y^2)^{1/2}}$$

(a) What is the form of this expression when $y \gg L$? (b) What is the form when $y \ll L$? (Refer to the table of integrals in Appendix C.)

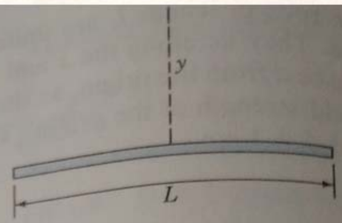


FIGURE 23.49 Problem 7.

11. (II) A dipole with a dipole moment p is pivoted freely at its midpoint. It lies in a uniform field. If its moment of inertia about the center is I, show that for small angular displacements, the dipole oscillates at a frequency

$$f = \frac{1}{2\pi}\sqrt{\frac{pE}{I}}$$

12. (II) A semi-infinite line of charge has a uniform charge density λ C/m. Find the field strength at a distance R from its end: (a) along the axis; (b) perpendicular to the axis. See Fig. 23.51.

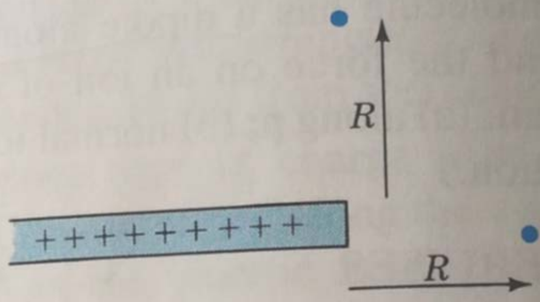


FIGURE 23.50 Problem 12.

16. (II) In Millikan's oil drop experiment, the drops are first held motionless by the application of a uniform field E. Next, the field is switched off and the drops are allowed to fall in air until they reach the terminal speed v_T. The fluid resistance is given by Stokes law, $F = 6\pi\eta r v_T$, where η is the coefficient of viscosity and r is the radius. The condition for falling at the terminal speed is

$$6\pi\eta r v_T = m_{\text{eff}}\, g$$

The effective mass of a drop is $m_{\text{eff}} = \frac{4}{3}\pi r^3(\rho - \rho_A)$ where ρ is the density of the drop and ρ_A is the density of the air—which has a buoyant effect. Show that the charge on a drop is given by

$$q = \frac{18\pi}{E}\sqrt{\frac{\eta^3 v_T^3}{2(\rho - \rho_A)g}}$$

(I) Two infinite and parallel sheets of charge have the same surface charge density σ C/m^2. What is the field (a) in the region between the sheets and (b) in the regions not between the sheets?

18. (I) A long, straight coaxial cable (Fig. 24.25) has an inner wire of radius a with a surface charge density σ and an outer cylindrical shell of radius b with $-\sigma$. Find the field in the regions (a) $a < r < b$, and (b) $r > b$.

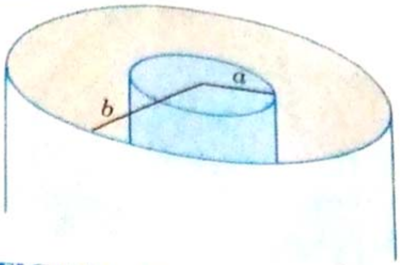


FIGURE 24.25 Exercises 17, 18, 19, 20, and 26.

ng, straight coaxial cabl...

1. (I) A positively charged metal sphere of radius a is at the center of a metal shell of radius b (Fig. 24.26). The spheres carry equal and opposite charges $\pm Q$. Find the electric field as a function of the distance r from the common center for (a) $a < r < b$, and (b) $r > b$.

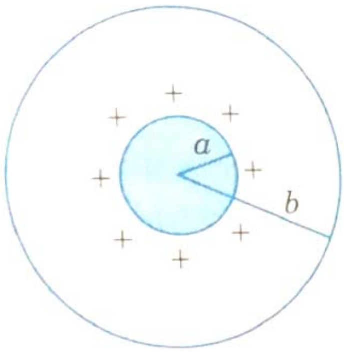


FIGURE 24.26 Exercises 21, 22, and 23.

4. (I) A conductor has a surface charge density σ C/m^2. Show that the force per unit area on the surface is $\sigma^2/2\varepsilon_0$ N/m^2. (*Hint:* The field at the surface has two contributions. Also, a static charge does not experience a force due to its own field.)

6. (I) A nonconducting sphere of radius R has a cavity of radius a at its center. The rest of the sphere has a uniform charge density ρ C/m^3 (Fig. 24.27). What is the electric field in the following regions: (a) $r > R$; (b) $a < r < R$? (*Hint:* The charge within a shell of thickness dr is $dq = \rho\, dV = \rho 4\pi r^2 dr$.)

$\frac{dq}{dr} = \boxed{\rho 4 \pi}$

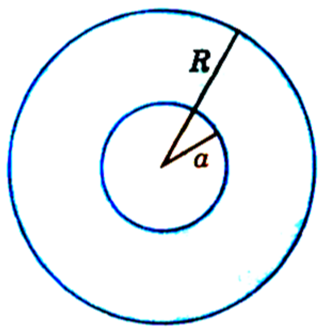
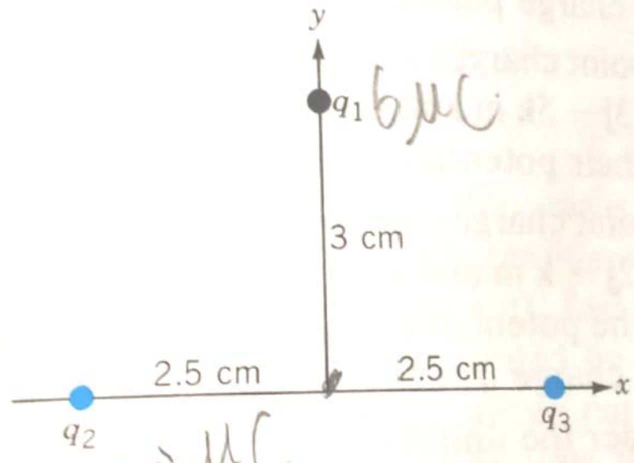


FIGURE 24.27 Problems 6 and 10.

31. (I) Three point charges, $q_1 = 6\ \mu C$, $q_2 = -2\ \mu C$, and q_3, are located as shown in Fig. 25.30. For what value of q_3 will the potential at the origin be: (a) 0 V; (b) -400 kV?



$V = \frac{kq}{r}$

FIGURE 25.30 Exercise 31.

37. (II) Carbon dioxide (CO_2) is an example of a linear quadrupole, shown in Fig. 25.32. Find the potential at a point (a) $(x, 0)$, and (b) $(0, y)$ for $y > a$. In each case, show that $V \propto 1/r^3$ for $r \gg a$, where r is the distance from the origin.

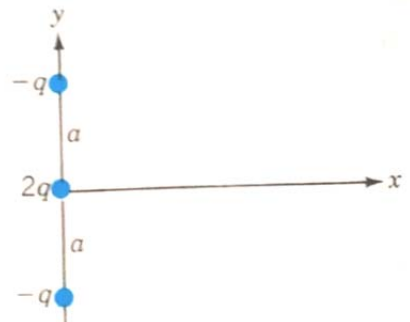


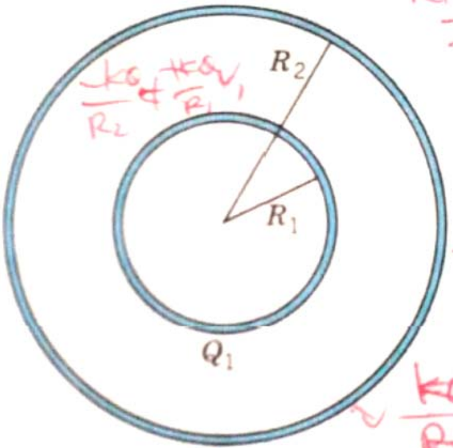
FIGURE 25.32 Exercise 37.

heat of tungsten is 134 J/kg · K.)

5. (I) A metal sphere of radius R_1 has a charge Q_1. It is enclosed by a conducting spherical shell of radius R_2 that has a charge $-Q_2$; see Fig. 25.34. Determine: (a) the potential V_1 of the inner sphere; (b) the potential V_2 of the outer sphere; (c) the potential difference $V_1 - V_2$. (d) Under what condition is $V_1 = V_2$?

$+\frac{kQ_1}{R_1}$

$+\frac{kQ_2}{R_2}$



$\rightarrow \frac{k(Q_1-Q_2)}{R_2}$

$\frac{kQ_1}{R_2} - \frac{kQ_2}{R_2} = V_2$

$-Q_2$

FIGURE 25.34 Problem 5.

6. (II) A balloon of radius R has a uniform surface charge density σ C/m^2. Show that the surface experiences an electrostatic force per unit area equal to $\sigma^2/2\varepsilon_0$ N/m^2. (*Hint:* Use the relation $F_r = dU/dr$.)

7. (I) A coaxial cable has an inner wire of radius a with a linear charge density λ C/m surrounded by a cylindrical sheath of radius b carrying a linear charge density $-\lambda$. (a) Use the electric field ($E = 2k\lambda/r$) between the wire and the sheath to show that the potential difference between them is

$$V(b) - V(a) = -2k\lambda \ln\left(\frac{b}{a}\right)$$

2. (I) A disk of radius b has a concentric hold of radius a. There is a uniform surface charge density σ. Find the potential at a point on the axis of the disk at a distance y from the center.

3. (I) In a NaCl crystal, Na^+ and Cl^- ions lie on a three-dimensional cubic array, as shown in Fig. 25.33. The nearest neighbor of any ion is at a distance 2.82×10^{-10} m. Find the potential energy of a Na^+ ion: (a) including only the contributions of the six nearest neighbors; (b) by including the contributions of the twelve next-nearest neighbors.

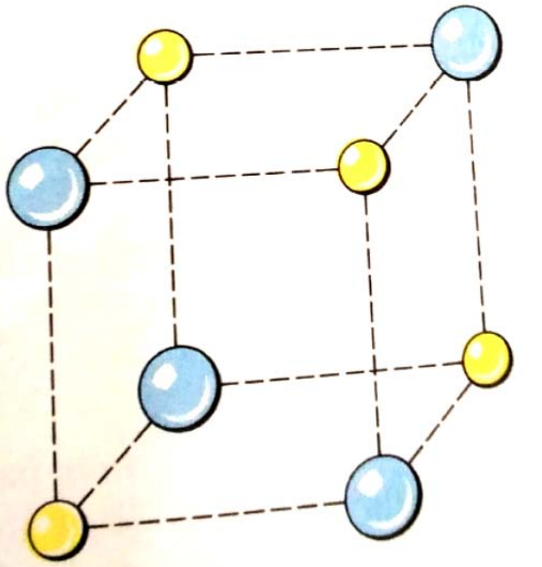


FIGURE 25.33 Problem 3.

45. (II) A sphere of radius R has a charge Q uniformly distributed throughout its volume. For $r < R$, the potential function is

$$V(r) = \frac{kQ(3R^2 - r^2}{2R^3}$$

Find the radial component of the electric field from $V(r)$.

46. (II) The potential $V(r)$ at a perpendicular distance r from an infinite line of charge with density λ C/m is

$$V(r) = V(r_0) - 2k\lambda \ln\left(\frac{r}{r_0}\right)$$

where r_0 and $V(r_0)$ are constants. From $V(r)$, find the electric field.

7. (II) A capacitor consists of two interleaving sets of plates, as shown in Fig. 26.22. The plate separations and the effective area of overlap are shown in the figure. What is the capacitance of this arrangement?

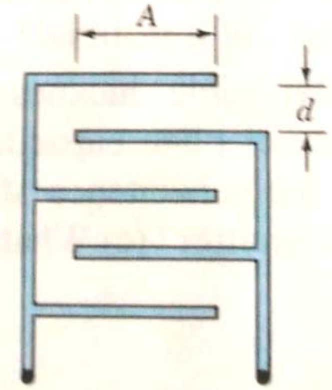


FIGURE 26.22 Exercise 7.

15. (I) The three capacitors in Fig. 26.24*a* have an equivalent capacitance of 12.4 μF. Find C_1.

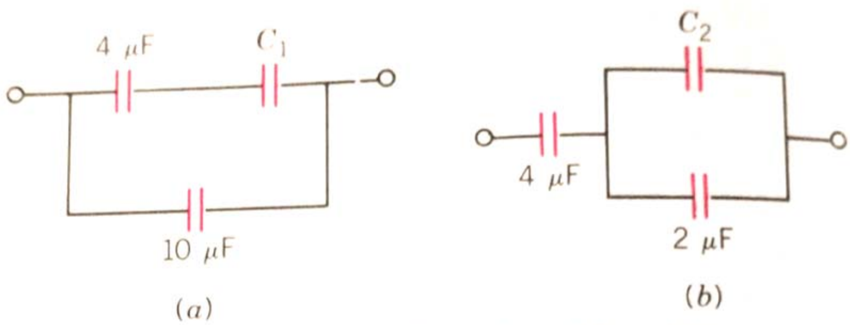


FIGURE 26.24 Exercises 15 and 16.

16. (I) The three capacitors in Fig. 26.24*b* have an equivalent capacitance of 2.77 μF. What is C_2?

34. (II) A parallel-plate capacitor with a plate separation d is connected to a battery with a potential difference V. The plates are pulled apart till the separation is $2d$. What is the change in each of the following quantities: (a) the potential difference; (b) the charge on each plate; (c) the energy stored in the capacitor?

35. (II) Repeat Exercise 34, with a charged capacitor but with the battery disconnected.

36. (I) Consider the combination of capacitors in Fig. 26.28. The energy stored in the 5-μF capacitor is 200 mJ. What is the energy stored in (a) the 4-μF capacitor, (b) the 3-μF capacitor?

$\frac{11}{3}V_2 = 20$

$V_2 = \frac{60}{11} \times \frac{8}{3}$

$V_1 = \frac{160}{11}$

$V_1 + V_2 = 20$

$\frac{11}{3}V_2 = 20$

$V_2 = \frac{60}{11}$

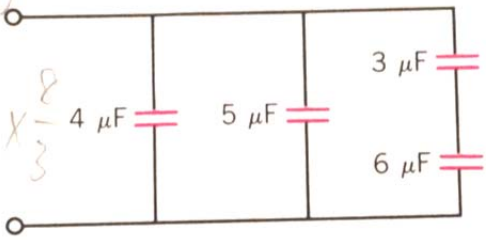


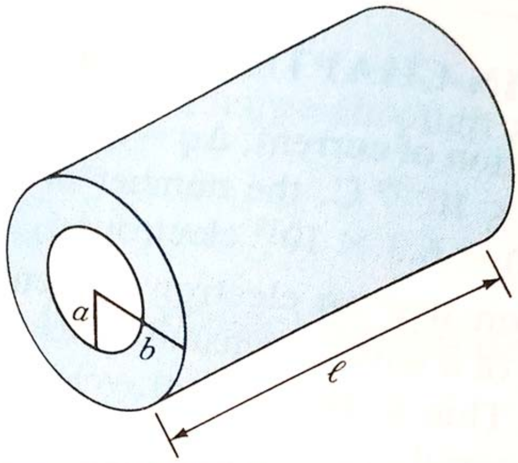
FIGURE 26.28 Exercise 36.

11. (II) A spherical capacitor consists of concentric spheres of radii R_1 and R_2. (a) Show that when $R_2 - R_1 \ll R_2$, the capacitance becomes that of a parallel-plate capacitor. (b) Show that in the appropriate limit the capacitance of the spherical capacitor reduces to that of an isolated sphere.

12. (II) (a) Find the energy density as a function of r for a cylindrical capacitor with an inner wire of radius a and an outer conductor of radius b. (b) What is the total energy stored in a length l of the capacitor? (c) Compare you result with a calculation based on $\frac{1}{2}CV^2$ or $Q^2/2C$.

6. (I) A 14-gauge copper wire of diameter 1.628 mm carries 15 A. Find: (a) the current density; (b) the drift velocity. The free electron density is 8.5×10^{28} m^{-3}.

13. (I) A cylindrical tube of length ℓ has an inner radius a and an outer radius b, as shown in Fig. 27.14. The resistivity is ρ. What is the resistance between the ends?



4. (II) A thick spherical shell has an inner radius a and an outer radius b. The material has resistivity ρ. Show that when a potential difference is applied between the inner and outer surfaces, the resistance is

$$R = \frac{(b-a)\rho}{4\pi ab}$$

$J = \frac{I}{4\pi r^2}$

$\Rightarrow E = J \cdot \rho$

9. (I) The ends of a copper and a steel wire, each 40 m long and of radius 1 mm, are connected together. A potential difference of 10 V is applied across the free ends. Find: (a) the power dissipated in each wire; (b) the electric field in each wire.

6. (II) A capacitor can be used to vary the times between flashes of a small neon gas tube with the circuit shown in Fig. 28.73. When cool, the gas is a good insulater. The tube "fires" (ionizes and emits light) when the potential difference across it reaches the firing value V_f. Its resistance becomes very small and so the capacitor rapidly discharges through it. As the potential difference drops the gas cools down and becomes an insulator at the "extinction" potential difference V_e. At this stage the capacitor again starts to charge. The variation of the potential difference across the capacitor and the tube is shown. Note that

$$V_e = V_0(1 - e^{-t/RC}); \qquad V_f = V_0(1 - e^{-(t+T)/RC})$$

where t is an unknown time and T is the period of the flashing show that,

$$T = RC \ln\left(\frac{V_0 - V_f}{V_0 - V_e}\right)$$

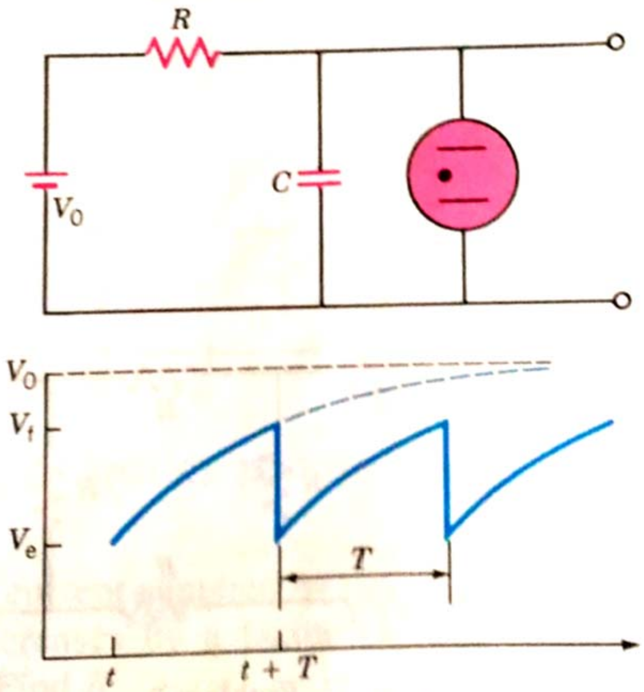


FIGURE 28.73 Problem 6.

9. (I) In the circuit of Fig. 28.75, switch S_1 is initially closed and S_2 is open. (a) Find $V_a - V_b$; (b) After S_2 is also closed, what is $V_a - V_b$? (c) S_1 is opened and S_2 is left closed. What is the time constant for the capacitor discharge?

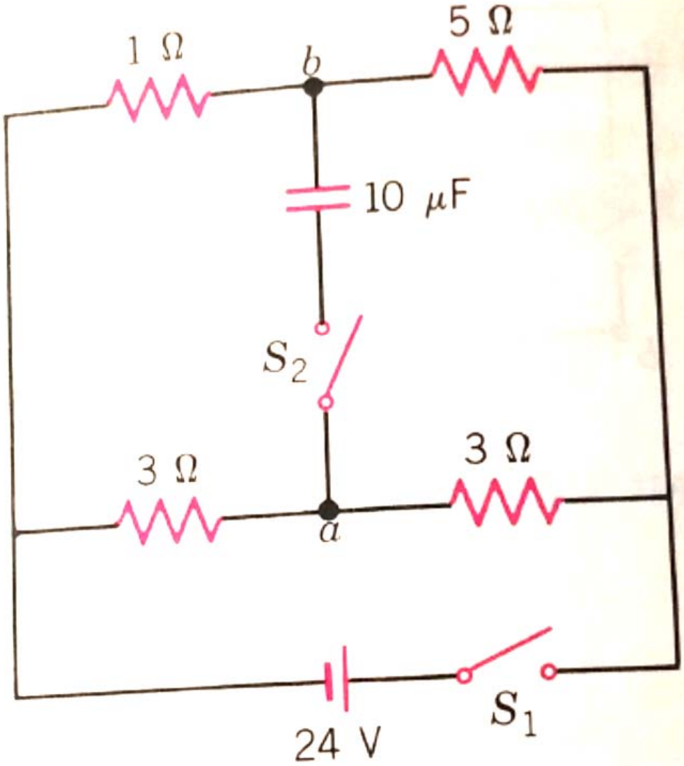


FIGURE 28.75 Problem 9.

11. (I) Find the current in each resistor in the circuit in Fig. 28.77.

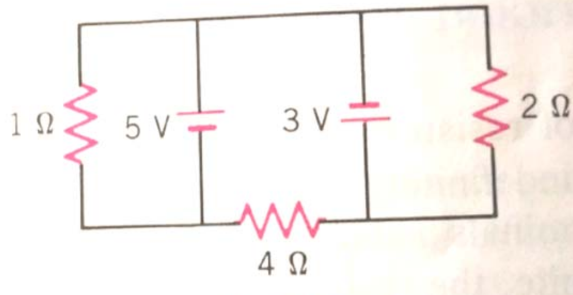


FIGURE 28.77 Problem 11.