1. A uniform electric field of magnitude 325 $\mathrm{V/m}$ is directed in the negative *y* direction in Figure P20.1. The coordinates of point Ⓐ are (−0.200, −0.300) m, and those of point Ⓑ are (0.400, 0.500) m. Calculate the electric potential difference $V_{Ⓑ} - V_{Ⓐ}$ using the dashed-line path.

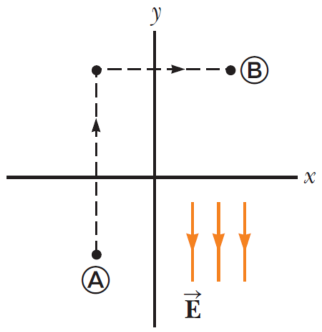


Figure P20.1

P20.1 The electric field is uniform. By Equation 20.3,

$$V_B - V_A = -\int_A^B \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}} = -\int_A^C \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}} - \int_C^B \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$

$$V_B - V_A = (-E\cos 180°)\int_{-0.300}^{0.500} dy - (E\cos 90.0°)\int_{-0.200}^{0.400} dx$$

$$V_B - V_A = (325\ \mathrm{V/m})(0.800\ \mathrm{m}) = \boxed{+260\ \mathrm{V}}$$

5. An electron moving parallel to the *x* axis has an initial speed of 3.70×10^6 $\mathrm{m/s}$ at the origin. Its speed is reduced to 1.40×10^5 $\mathrm{m/s}$ at the point *x* = 2.00 cm. (a) Calculate the electric potential difference between the origin and that point. (b) Which point is at the higher potential?

P20.5 We use the energy version of the isolated system model to equate the energy of the electron-field system when the electron is at $x = 0$ to the energy when the electron is at $x = 2.00$ cm. The unknown will be the difference in potential $V_f - V_i$. Thus, $K_i + U_i = K_f + U_f$ becomes

$$\frac{1}{2}mv_i^2 + qV_i = \frac{1}{2}mv_f^2 + qV_f$$

or $$\frac{1}{2}m\left(v_i^2 - v_f^2\right) = q\left(V_f - V_i\right),$$

so $$V_f - V_i = \Delta V = \frac{m\left(v_i^2 - v_f^2\right)}{2q}.$$

(a) Noting that the electron's charge is negative, and evaluating the potential difference, we have

$$\Delta V = \frac{\left(9.11\times10^{-31}\ \text{kg}\right)\left[(3.70\times10^{6}\ \text{m/s})^2-(1.40\times10^{5}\ \text{m/s})^2\right]}{2\left(-1.60\times10^{-19}\ \text{C}\right)}$$

$$= \boxed{-38.9\ \text{V}}$$

(b) The negative sign means that the 2.00-cm location is lower in potential than the origin:

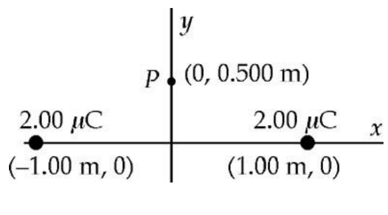
$$\Delta V = \boxed{-38.9\ \text{V. The origin is at highest potential.}}$$

7. Two particles each with charge +2.00 μC are located on the x axis. One is at x = 1.00 m, and the other is at x = −1.00 m. (a) Determine the electric potential on the y axis at y = 0.500 m. (b) Calculate the change in electric potential energy of the system as a third charged particle of −3.00 μC is brought from infinitely far away to a position on the y axis at y = 0.500 m.

P20.7 (a) $V = \frac{k_e q_1}{r_1} + \frac{k_e q_2}{r_2} = 2\left(\frac{k_e q}{r}\right)$

$$V = 2\left(\frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(2.00\times10^{-6}\ \text{C}\right)}{\sqrt{(1.00\ \text{m})^2+(0.500\ \text{m})^2}}\right)$$

$$V = 3.22\times10^{4}\ \text{V} = \boxed{32.2\ \text{kV}}$$



ANS. FIG. P20.7

(b) $U = qV = \left(-3.00\times10^{-6}\ \text{C}\right)\left(3.22\times10^{4}\ \text{J/C}\right) = \boxed{-9.65\times10^{-2}\ \text{J}}$

14. Two charged particles create influences at the origin, described by the expressions

$$8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}\left[-\frac{7.00\times10^{-9}\mathrm{C}}{(0.070\,0\mathrm{m})^2}\cos70.0°\hat{\mathbf{i}}\right.$$
$$\left.-\frac{7.00\times10^{-9}\mathrm{C}}{(0.070\,0\mathrm{m})^2}\sin70.0°\hat{\mathbf{j}}+\frac{8.00\times10^{-9}\mathrm{C}}{(0.030\,0\mathrm{m})^2}\hat{\mathbf{j}}\right]$$

and

$$8.99\times10^{9}\ \mathrm{N\cdot m^2/C^2}\left[\frac{7.00\times10^{-9}\mathrm{C}}{0.070\,0\mathrm{m}}-\frac{8.00\times10^{-9}\mathrm{C}}{0.030\,0\mathrm{m}}\right]$$

(a) Identify the locations of the particles and the charges on them. (b) Find the force on a −16.0 nC charge placed at the origin and (c) the work required to move this third charge to the origin from a very distant point.

P20.14 (a) The first expression, with distances squared, describes an electric field. The second expression describes an electric potential. Then a $\boxed{\text{positive 7.00-nC charge}}$ is 7.00 cm from the origin. To create a field that is to the left and downward, it must be in the first quadrant, with position vector $\boxed{\text{7.00 cm at 70.0°}}$. A $\boxed{\text{negative 8.00-nC charge}}$ 3.00 cm from the origin creates an upward electric field at the origin, so it must be at $\boxed{\text{3.00 cm at 90.0°}}$. We evaluate the given expressions:

$$\vec{\mathbf{E}}=-4.39\ \mathrm{kN/C}\,\hat{\mathbf{i}}+67.8\ \mathrm{kN/C}\,\hat{\mathbf{j}}$$
$$V=-1.50\ \mathrm{kV}$$

(b) $\vec{\mathbf{F}}=q\vec{\mathbf{E}}=\left(-16.0\times10^{-9}\ \mathrm{C}\right)\left(-4.39\hat{\mathbf{i}}+67.8\hat{\mathbf{j}}\right)\times10^{3}\ \mathrm{N/C}$

$$=\boxed{\left(7.03\hat{\mathbf{i}}-109\hat{\mathbf{j}}\right)\times10^{-5}\ \mathrm{N}}$$

(c) $U_e=qV=\left(-16.0\times10^{-9}\ \mathrm{C}\right)\left(-1.50\times10^{3}\ \mathrm{J/C}\right)=\boxed{2.40\times10^{-5}\ \mathrm{J}}$

19. Two particles, with charges of 20.0 nC and −20.0 nC, are placed at the points with coordinates (0, 4.00 cm) and (0, −4.00 cm) as shown in Figure P20.19. A particle with charge 10.0 nC is located at the origin. (a) Find the electric potential energy of the configuration of the three fixed charges. (b) A fourth particle, with a mass of 2.00×10^{-13} kg and a charge of 40.0 nC, is released from rest at the point (3.00 cm, 0). Find its speed after it has moved freely to a very large distance away.

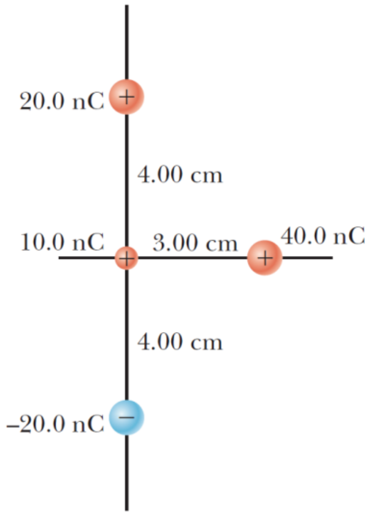


Figure P20.19

P20.19 (a) In an empty universe, the 20.0-nC charge can be placed at its location with no energy investment. At a distance of 4.00 cm, it creates a potential

$$V_1 = \frac{k_e q_1}{r} = \frac{(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2)(20.0\times10^{-9}\ \text{C})}{0.040\ 0\ \text{m}} = 4.50\ \text{kV}$$

To place the 10.0-nC charge there we must put in energy

$$U_{12} = q_2 V_1 = (10.0\times10^{-9}\ \text{C})(4.50\times10^3\ \text{V}) = 4.50\times10^{-5}\ \text{J}$$

Next, to bring up the –20.0-nC charge requires energy

$$\begin{aligned} U_{23} + U_{13} &= q_3 V_2 + q_3 V_1 = q_3(V_2 + V_1) \\ &= (-20.0\times10^{-9}\ \text{C})(8.99\times10^9\ \text{N}\cdot\text{m}^2/\text{C}^2) \\ &\quad \times\left(\frac{10.0\times10^{-9}\ \text{C}}{0.040\ 0\ \text{m}} + \frac{20.0\times10^{-9}\ \text{C}}{0.080\ 0\ \text{m}}\right) \\ &= -4.50\times10^{-5}\ \text{J} - 4.50\times10^{-5}\ \text{J} \end{aligned}$$

The total energy of the three charges is

$$U_{12} + U_{23} + U_{13} = \boxed{-4.50\times10^{-5}\ \text{J}}$$

(b) The three fixed charges create this potential at the location where the fourth is released:

$$
\begin{aligned}
V &= V_1 + V_2 + V_3 \\
&= \left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right) \\
&\quad\times\left(\frac{20.0\times10^{-9}\ \text{C}}{\sqrt{(0.040\ 0\ \text{m})^2+(0.030\ 0\ \text{m})^2}}\right. \\
&\qquad\left.+\frac{10.0\times10^{-9}\ \text{C}}{0.030\ 0\ \text{m}}-\frac{20.0\times10^{-9}\ \text{C}}{0.050\ 0\ \text{m}}\right) \\
V &= 3.00\times10^{3}\ \text{V}
\end{aligned}
$$

Energy of the system of four charged objects is conserved as the fourth charge flies away:

$$\left(\frac{1}{2}mv^2+qV\right)_i=\left(\frac{1}{2}mv^2+qV\right)_f$$

$$0+\left(40.0\times10^{-9}\ \text{C}\right)\left(3.00\times10^{3}\ \text{V}\right)=\frac{1}{2}\left(2.00\times10^{-13}\ \text{kg}\right)v^2+0$$

$$v=\sqrt{\frac{2\left(1.20\times10^{-4}\ \text{J}\right)}{2\times10^{-13}\ \text{kg}}}=\boxed{3.46\times10^{4}\ \text{m/s}}$$

23. Over a certain region of space, the electric potential is $V = 5x - 3x^2y + 2yz^2$. (a) Find the expressions for the *x*, *y*, and *z* components of the electric field over this region. (b) What is the magnitude of the field at the point *P* that has coordinates (1.00, 0, −2.00) m?

P20.23 (a) $V = 5x - 3x^2y + 2yz^2$, where *x*, *y* and *z* are in meters and *V* is in volts.

$$
\begin{aligned}
E_x &= -\frac{\partial V}{\partial x} = -5+6xy \\
E_y &= -\frac{\partial V}{\partial y} = +3x^2-2z^2 \\
E_z &= -\frac{\partial V}{\partial z} = -4yz
\end{aligned}
$$

which gives

$$\boxed{\vec{\mathbf{E}}=\left(-5+6xy\right)\hat{\mathbf{i}}+\left(3x^2-2z^2\right)\hat{\mathbf{j}}-4yz\hat{\mathbf{k}}}$$

(b) Evaluate *E* at (1.00, 0, −2.00) m, suppressing units,

$$E_x = -5 + 6(1.00)(0) = -5.00$$
$$E_y = 3(1.00)^2 - 2(-2.00)^2 = -5.00$$
$$E_z = -4(0)(-2.00) = 0$$

which gives

$$E = \sqrt{E_x^2 + E_y^2 + E_z^2} = \sqrt{(-5.00)^2 + (-5.00)^2 + 0^2} = \boxed{7.07\ \text{N/C}}$$

26. **S** A rod of length *L* (Fig. P20.26) lies along the *x* axis with its left end at the origin. It has a nonuniform charge density $\lambda = \alpha x$, where α is a positive constant, (a) What are the units of α? (b) Calculate the electric potential at *A*.

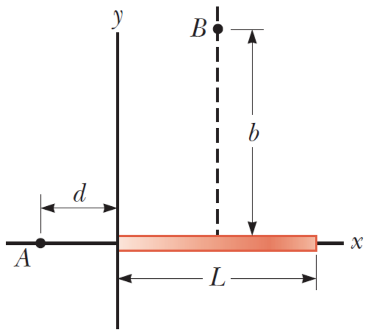
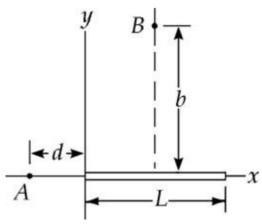


Figure P20.26 Problems 26 and 27.

P20.26 (a) As a linear charge density, λ has units of C/m. So $\alpha = \lambda/x$ must have units of C/m^2:

$$[\alpha] = \left[\frac{\lambda}{x}\right] = \frac{\text{C}}{\text{m}} \cdot \left(\frac{1}{\text{m}}\right) = \boxed{\frac{\text{C}}{\text{m}^2}}$$



ANS. FIG. P20.26

(b) Consider a small segment of the rod at location *x* and of length *dx*. The amount of charge on it is $\lambda\, dx = (\alpha x)\, dx$. Its distance from *A* is *d* + *x*, so its contribution to the electric potential at *A* is

$$dV = k_e \frac{dq}{r} = k_e \frac{\alpha x\, dx}{d + x}$$

Relative to $V = 0$ infinitely far away, to find the potential at *A* we must integrate these contributions for the whole rod, from $x = 0$ to $x = L$. Then $V = \int_{\text{all } q} dV = \int_0^L \frac{k_e \alpha x}{d + x}\, dx.$

To perform the integral, make a change of variables to

$u = d + x$, $du = dx$, $u(\text{at } x = 0) = d$, and $u(\text{at } x = L) = d + L$:

$$V = \int_d^{d+L} \frac{k_e\alpha(u-d)}{u}\,du = k_e\alpha\int_d^{d+L} du - k_e\alpha d\int_d^{d+L}\left(\frac{1}{u}\right) du$$

$$V = k_e\alpha u\Big|_d^{d+L} - k_e\alpha d\ln\, u\Big|_d^{d+L}$$
$$= k_e\alpha(d+L-d) - k_e\alpha d\left[\ln(d+L) - \ln\, d\right]$$

$$V = \boxed{k_e\alpha\left[L - d\ln\left(1+\frac{L}{d}\right)\right]}$$

28. **S** A wire having a uniform linear charge density λ is bent into the shape shown in Figure P20.28. Find the electric potential at point *O*.

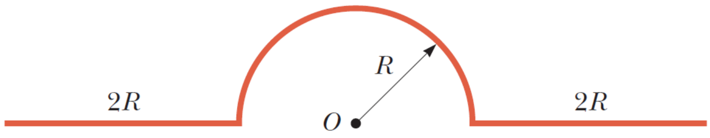


Figure P20.28

P20.28 $$V = k_e \int\limits_{\text{all charge}} \frac{dq}{r} = k_e \int_{-3R}^{-R} \frac{\lambda dx}{-x} + k_e \int\limits_{\text{semicircle}} \frac{\lambda ds}{R} + k_e \int_R^{3R} \frac{\lambda dx}{x}$$

$$V = -k_e\lambda\ln(-x)\Big|_{-3R}^{-R} + \frac{k_e\lambda}{R}\pi R + k_e\lambda\ln x\Big|_R^{3R}$$
$$V = k_e\lambda\ln\frac{3R}{R} + k_e\lambda\pi + k_e\lambda\ln 3 = \boxed{k_e\lambda(\pi + 2\ln 3)}$$

32. A spherical conductor has a radius of 14.0 cm and charge of 26.0 μC. Calculate the electric field and the electric potential (a) r = 10.0 cm, (b) r = 20.0 cm, and (c) r = 14.0 cm from the center.

P20.32 For points on the surface and outside, the sphere of charge behaves like a charged particle at its center, both for creating field and potential.

(a) Inside a conductor when charges are not moving, the electric field is zero and the potential is uniform, the same as on the surface, and $E = \boxed{0}$.

$$V = \frac{k_e q}{R} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(26.0\times10^{-6}\ \text{C}\right)}{0.140\ \text{m}} = \boxed{1.67\ \text{MV}}$$

(b) $$E = \frac{k_e q}{r^2} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(26.0\times10^{-6}\ \text{C}\right)}{(0.200\ \text{m})^2}$$

$$= \boxed{5.84\ \text{MN/C}}\ \text{away}$$

$$V = \frac{k_e q}{R} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(26.0\times10^{-6}\ \text{C}\right)}{0.200\ \text{m}} = \boxed{1.17\ \text{MV}}$$

(c) $$E = \frac{k_e q}{R^2} = \frac{\left(8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2\right)\left(26.0\times10^{-6}\ \text{C}\right)}{(0.140\ \text{m})^2}$$

$$= \boxed{11.9\ \text{MN/C}}\ \text{away}$$

$$V = \frac{k_e q}{R} = \boxed{1.67\ \text{MV}}$$

35. An isolated, charged conducting sphere of radius 12.0 cm creates an electric field of 4.90×10^4 N/C at a distance 21.0 cm from its center. (a) What is its surface charge density? (b) What is its capacitance?

P20.35 (a) The electric field outside a spherical charge distribution of radius R is $E = k_e q/r^2$. Therefore,

$$q = \frac{Er^2}{k_e} = \frac{\left(4.90\times10^{4}\ \text{N/C}\right)(0.210\ \text{m})^2}{8.99\times10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2} = 0.240\ \mu\text{C}$$

Then

$$\sigma = \frac{q}{A} = \frac{0.240\times10^{-6}\ \text{C}}{4\pi(0.120\ \text{m})^2} = \boxed{1.33\ \mu\text{C/m}^2}$$

(b) For an isolated charged sphere of radius R,

$$C = 4\pi \in_0 r = 4\pi\left(8.85\times10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2\right)(0.120\ \text{m}) = \boxed{13.3\ \text{pF}}$$

38. **S** A variable air capacitor used in a radio tuning circuit is made of *N* semicircular plates, each of radius *R* and positioned a distance *d* from its neighbors, to which it is electrically connected. As shown in Figure P20.38, a second identical set of plates is enmeshed with the first set. Each plate in the second set is halfway between two plates of the first set. The second set can rotate as a unit. Determine the capacitance as a function of the angle of rotation ϑ, where $\vartheta = 0$ corresponds to the maximum capacitance.

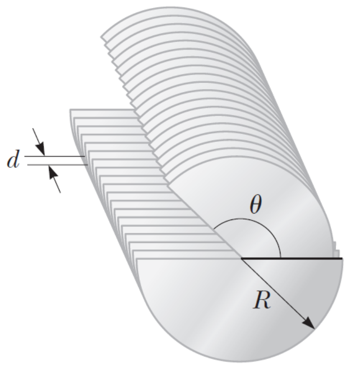
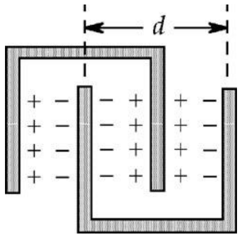


Figure P20.38

P20.38 With $\theta = \pi$, the plates are out of mesh and the overlap area is zero. With $\theta = 0$, the overlap area is that of a semi-circle, $\frac{\pi R^2}{2}$. By proportion, the effective area of a single sheet of charge is

$$\frac{(\pi - \theta)R^2}{2}$$



ANS. FIG. P20.38

When there are two plates in each comb, the number of adjoining sheets of positive and negative charge is 3, as shown in the sketch. When there are *N* plates on each comb, the number of parallel capacitors is $2N - 1$ and the total capacitance is

$$C = (2N-1)\frac{\epsilon_0 A_{\text{effective}}}{\text{distance}} = \frac{(2N-1)\epsilon_0(\pi-\theta)R^2/2}{d/2}$$

$$= \boxed{\frac{(2N-1)\epsilon_0(\pi-\theta)R^2}{d}}$$

45. Four capacitors are connected as shown in Figure P20.45. (a) Find the equivalent capacitance between points *a* and *b*. (b) Calculate the charge on each capacitor, taking $\Delta V_{ab} = 15.0\text{ V}$.

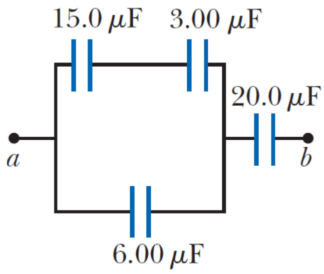


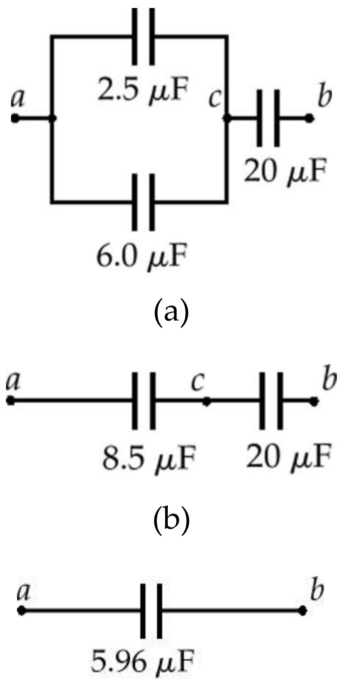
Figure P20.45

P20.45 (a) We simplify the circuit of Figure P20.45 in three steps as shown in ANS. FIG. P20.45 panels (a), (b), and (c). First, the 15.0-μF and 3.00-μF capacitors in series are equivalent to

$$\frac{1}{(1/15.0\ \mu\text{F})+(1/3.00\ \mu\text{F})}=2.50\ \mu\text{F}$$

Next, the 2.50-μF capacitor combines in parallel with the 6.00-μF capacitor, creating an equivalent capacitance of 8.50 μF. At last, this 8.50-μF equivalent capacitor and the 20.0-μF capacitor are in series, equivalent to

$$\frac{1}{(1/8.50\ \mu\text{F})+(1/20.00\ \mu\text{F})}=\boxed{5.96\ \mu\text{F}}$$



ANS. FIG. P20.45

(b) We find the charge on each capacitor and the voltage across each by working backwards through solution figures (c)–(a), alternately applying $Q = C\Delta V$ and $\Delta V = Q/C$ to every capacitor, real or equivalent. For the 5.96-μF capacitor, we have

$$Q = C\Delta V = (5.96\ \mu\text{F})(15.0\ \text{V}) = \boxed{89.5\ \mu\text{C}}$$

Thus, if *a* is higher in potential than *b*, just 89.5 μC flows between the wires and the plates to charge the capacitors in each picture. In (b) we have, for the 8.5-μF capacitor,

$$\Delta V_{ac} = \frac{Q}{C} = \frac{89.5\ \mu\text{C}}{8.50\ \mu\text{F}} = 10.5\ \text{V}$$

and for the 20.0-μF capacitor in (b), (a), and the original circuit, we have $Q_{20} = 89.5\ \mu$C. Then

$$\Delta V_{cb} = \frac{Q}{C} = \frac{89.5\ \mu\text{C}}{20.0\ \mu\text{F}} = 4.47\ \text{V}$$

Next, the circuit in diagram (a) is equivalent to that in (b), so $\Delta V_{cb} = 4.47$ V and $\Delta V_{ac} = 10.5$ V.

For the 2.50-μF capacitor, $\Delta V = 10.5$ V and

$$Q = C\Delta V = (2.50\ \mu\text{F})(10.5\ \text{V}) = \boxed{26.3\ \mu\text{C}}$$

For the 6.00-μF capacitor, $\Delta V = 10.5$ V and

$$Q_6 = C\Delta V = (6.00\ \mu\text{F})(10.5\ \text{V}) = \boxed{63.2\ \mu\text{C}}$$

Now, 26.3 μC having flowed in the upper parallel branch in (a), back in the original circuit we have $Q_{15} = 26.3\ \mu$C and

$Q_3 = 26.3\ \mu$C.

51. Find the equivalent capacitance between points *a* and *b* in the combination of capacitors shown in Figure P20.51.

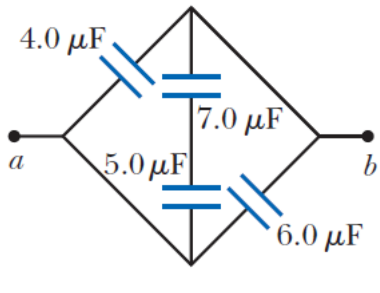
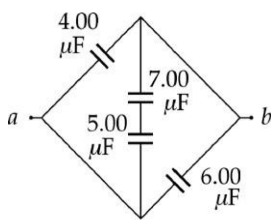


Figure P20.51

P20.51

$$C_s = \left(\frac{1}{5.00} + \frac{1}{7.00}\right)^{-1} = 2.92\ \mu\text{F}$$

$$C_p = 2.92 + 4.00 + 6.00 = \boxed{12.9\ \mu\text{F}}$$



ANS. FIG. P20.51

55. Calculate the work that must be done on charges brought from infinity to charge a spherical shell of radius R = 0.100 m to a total charge Q = 125 μC.

P20.55 $W = \int_0^Q V dq$, where $V = \frac{k_e q}{R}$.

Therefore,

$$W = \frac{k_e Q^2}{2R} = \frac{(8.99\times10^9 \text{ N}\cdot\text{m}^2/\text{C}^2)(125\times10^{-6}\text{ C})^2}{2(0.100\text{ m})} = \boxed{702\text{ J}}.$$

64. **S** A Geiger – Mueller tube is a radiation detector that consists of a closed, hollow, metal cylinder (the cathode) of inner radius r_a and a coaxial cylindrical wire (the anode) of radius r_b (Fig. P20.64a). The charge per unit length on the anode is λ, and the charge per unit length on the cathode is $-\lambda$. A gas fills the space between the electrodes. When the tube is in use (Fig. P20.64b) and a high-energy elementary particle passes through this space, it can ionize an atom of the gas. The strong electric field makes the resulting ion and electron accelerate in opposite directions. They strike other molecules of the gas to ionize them, producing an avalanche of electrical discharge. The pulse of electric current between the wire and the cylinder is counted by an external circuit. (a) Show that the magnitude of the electric potential difference between the wire and the cylinder is

$$\Delta V = 2k_e\lambda \ln\left(\frac{r_a}{r_b}\right)$$

(b) Show that the magnitude of the electric field in the space between cathode and anode is

$$E = \frac{\Delta V}{\ln(r_a/r_b)}\left(\frac{1}{r}\right)$$

where r is the distance from the axis of the anode to the point where the field is to be calculated.

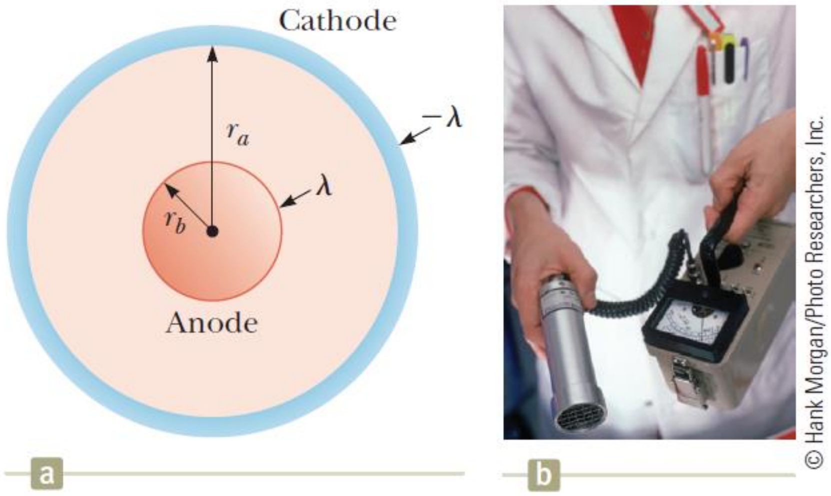
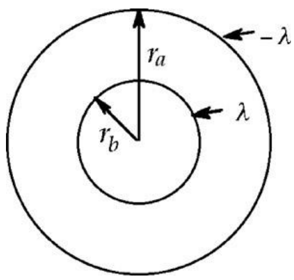


Figure P20.64 Problems 64 and 65.

P20.64 (a) $V_B - V_A = -\int_A^B \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$ and the field at distance r from a uniformly charged rod (where $r >$ radius of charged rod) is

$$E = \frac{\lambda}{2\pi \epsilon_0 r} = \frac{2k_e\lambda}{r}$$



ANS. FIG. P20.64

In this case, the field between the central wire and the coaxial cylinder is directed perpendicular to the line of charge so that

$$V_B - V_A = -\int_{r_a}^{r_b} \frac{2k_e\lambda}{r} dr = 2k_e\lambda \ln\left(\frac{r_a}{r_b}\right)$$

or $\boxed{\Delta V = 2k_e\lambda \ln\left(\frac{r_a}{r_b}\right)}$.

(b) From part (a), when the outer cylinder is considered to be at zero potential, the potential at a distance r from the axis is

$$V = 2k_e\lambda \ln\left(\frac{r_a}{r}\right)$$

The field at r is given by

$$E=-\frac{\partial V}{\partial r}=-2k_e\lambda\left(\frac{r}{r_a}\right)\left(-\frac{r_a}{r^2}\right)=\frac{2k_e\lambda}{r}$$

But, from part (a), $2k_e\lambda=\frac{\Delta V}{\ln(r_a/r_b)}$.

Therefore, $\boxed{E=\frac{\Delta V}{\ln(r_a/r_b)}\left(\frac{1}{r}\right)}$