Chapter 24

Electric Potential

(9)

••9 An infinite nonconducting sheet has a surface charge density $\sigma = +5.80\ \text{pC/m}^2$. (a) How much work is done by the electric field due to the sheet if a particle of charge $q = +1.60 \times 10^{-19}$ C is moved from the sheet to a point P at distance $d = 3.56$ cm from the sheet? (b) If the electric potential V is defined to be zero on the sheet, what is V at P?

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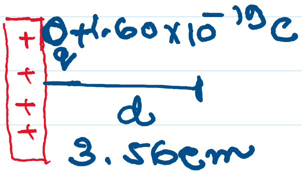
(a)

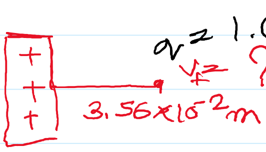


$\sigma = 5.80\ \text{pC/m}^2$

We know

$$W = F.d$$
$$= F.d\cos\theta$$
$$= qE.d\cos\theta$$
$$= q\frac{\sigma}{2\epsilon_0}d\cos\theta$$
$$= \frac{1.60\times10^{-19}\times3.56\times10^{-2}\times5.8\times10^{-12}}{2\times8.85\times10^{-12}}$$
$$= 1.87\times10^{-21}\ \text{J}$$

(b)



$V_0 = 0V$

We know,

$$V_f - V_0 = -W \qquad \left[V = \frac{J}{C} \qquad V = \frac{W}{q} \right]$$

So, $V_f = -\frac{W}{q} + V_0$

$= -\frac{W}{q} + V_0$

So, $V_f = -\frac{W}{q} + V_0$ $\left[V = -\frac{W}{q} \right]$

$= -\frac{W}{q} + V_0$

$= 1.87 \times 10^{-21} \times 1.60 \times 10^{-19}$

$= 3 \times 10^{40}$ V

(13)

•13 What are (a) the charge and (b) the charge density on the surface of a conducting sphere of radius 0.15 m whose potential is 200 V (with $V = 0$ at infinity)?

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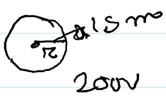
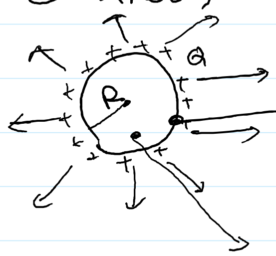


$k = (4\pi\epsilon_0)^{-1}$

(a)

we know,



→ Point at, $P(r > R)$

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

at surface, $P(r = R)$

$V = \frac{kQ}{R}$

inside sphere

$E = \frac{-\Delta V}{\Delta r}$

$0 = \frac{-\Delta V}{\Delta r}$

$\Delta V = 0$ pd $= 0$

$\Delta r = 0$

So, we can tell

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

$V = \frac{q}{4\pi\epsilon_0 r}$

$q = 4\pi\epsilon_0 r V = (8.99\times10^{9}) \times 200 \times 0.15$

$= 3.3\times10^{-9}$ C (Ans)

(b)

we know

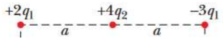
$$\frac{q}{A} = 6$$

$$6 = \frac{3.3\times10^{-9}}{4\pi R^2} = \frac{3.3\times10^{-9}}{4\times3.1415\times(0.15)^2}$$

$$= 1.2\times10^{-8}\ C\,m^{-2}$$

(Ans)

••15 SSM ILW A spherical drop of water carrying a charge of 30 pC has a potential of 500 V at its surface (with $V = 0$ at infinity). (a) What is the radius of the drop? (b) If two such drops of the same charge and radius combine to form a single spherical drop, what is the potential at the surface of the new drop?



••15 A spherical drop of water carrying a charge of 30
pC has a potential of 500 V at its surface (with V 0 at
infinity).
(a) What is the radius of the drop? (b) If two such drops of
the
same charge and radius combine to form a single spherical
drop,
what is the potential at the surface
of the new drop?

we know,

$$V = \frac{q}{4\pi\epsilon_0 r}$$

we know

$$\left[V = \frac{E}{r} = \frac{\frac{q}{4\pi\epsilon_0}}{r} \right]$$

$$r = \frac{q}{4\pi\epsilon_0 v}$$

$$r = \frac{30\times10^{-12}}{(8.99\times10^{9})^{-1}\times500}$$

$$r = 5.9\times10^{-4}\ m$$

(b)

we know

if 2 drop combines

final volume would be

$$V_f = 2\left(\frac{4}{3}\pi r^3\right)$$

$$\cancel{\frac{4}{3}}\cancel{\pi} r'^3 = \frac{\cancel{8}^{2}}{\cancel{3}}\cancel{\pi} r^3$$

$$= 2r^3$$

$$r' = \sqrt[3]{2}\, r$$

And charge would add up

So,

$$q' = 2q$$

we know potential at surface would be

$$V = \frac{E}{r'} = \frac{\frac{q'}{4\pi\epsilon_0}}{r'}$$

$$V = \frac{q'}{4\pi\epsilon_0 r'} = \frac{2\times 30\times 10^{-12}}{8.99\times 10^{-9}\times\sqrt[3]{2}\times 0.15}$$

$$= 790\ V$$

what is the potential at the surface of the new drop?

••16 GO Figure 24-37 shows a rectangular array of charged particles fixed in place, with distance $a = 39.0$ cm and the charges shown as integer multiples of $q_1 = 3.40$ pC and $q_2 = 6.00$ pC. With $V = 0$ at infinity, what is the net electric potential at the rectangle's center? (*Hint:* Thoughtful examination of the arrangement can reduce the calculation.)

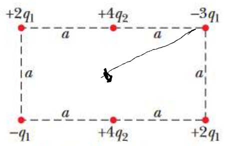
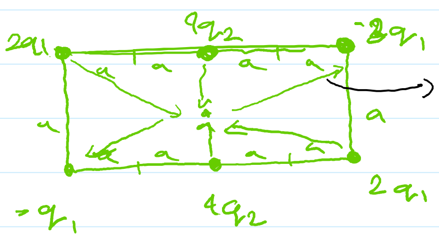


Figure 24-37 Problem 16.

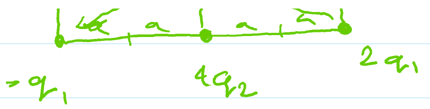
$$\frac{q}{r} \quad 4\pi\epsilon_0$$

••16 Figure 24-37 shows a rectangular array of charged particles fixed in place, with distance a 39.0 cm and the charges shown as integer multiples of q1 $ 3.40 pC and q2 $ 6.00 pC. With V $ 0 at infinity, what is the net electric potential at the rectangle's center? (Hint: Thoughtful examination of the arrangement can reduce the calculation.)



$$r = \sqrt{(a)^2 + \left(\frac{a}{2}\right)^2}$$

$$r = \sqrt{a^2 + \frac{a^2}{4}}$$



$$r = \sqrt{a^2 + \frac{a^2}{4}}$$

$$= \sqrt{\frac{4a^2 + a^2}{4}} = \frac{\sqrt{5}a}{2}$$

$$V = \frac{-q_1}{\frac{\sqrt{5}a}{2}} - \frac{3q_1}{\frac{\sqrt{5}a}{2}} + \frac{2q_1}{\frac{\sqrt{5}a}{2}}$$

$$= \frac{2q_1}{\frac{\sqrt{5}a}{2}} + \frac{4q_2}{a/2} + \frac{4q_2}{a/2}$$

$$= \frac{16 q_2}{a} = \frac{16 \times (3.9 \times 10^{-12})}{39 \times 10^{-3}}$$

$$= 2.21 V$$

(Ans)

Module 24-4 Potential Due to an Electric Dipole

•21 ILW The ammonia molecule NH_3 has a permanent electric dipole moment equal to 1.47 D, where 1 D = 1 debye unit = 3.34×10^{-30} C·m. Calculate the electric potential due to an ammonia molecule at a point 52.0 nm away along the axis of the dipole. (Set $V = 0$ at infinity.)

•21 The ammonia molecule NH3 has a permanent electric
dipole moment equal to 1.47 D, where 1 D 1 debye unit
3.34 10'30 C #m. Calculate the electric potential due to an
am-
monia molecule at a point 52.0 nm away along the axis of the
dipole. (Set V $ 0 at infinity.)

we know,

$p = dq$

NH_3 $p = 1.47 \times 3.34 \times 10^{-30}$ C.m

We know,

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

$1 \qquad rq,$

$$V = \frac{1}{4\pi\epsilon_0} \frac{\quad}{r}$$

$$= \frac{1}{4\pi\epsilon_0} \frac{rq}{r^2}$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{p}{r^2}$$

$$V = 8.99\times10^{9} \times \frac{3.34\times10^{-30}\times 1.47}{(5.2\times10^{-9})^2}$$

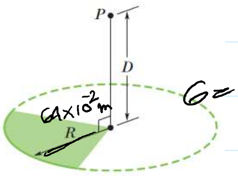
$$V = 1.6324\times10^{-3}\ \frac{J}{C}$$

(Ans.)

moment that is perpendicular to a radial line and has a magnitude of 1.28×10^{-21} C·m.

What is the net electric potential at the center?

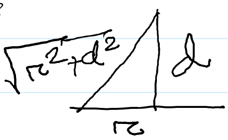
••31 SSM WWW A plastic disk of radius $R = 64.0$ cm is charged on one side with a uniform surface charge density $\sigma = 7.73$ fC/m^2, and then three quadrants of the disk are removed. The remaining quadrant is shown in Fig. 24-50. With $V = 0$ at infinity, what is the potential due to the remaining quadrant at point P, which is on the central axis of the original disk at distance $D = 25.9$ cm from the original center?



$\sigma = 7.73$ fC/m^2

Figure 24-50 Problem 31.

••31 A plastic disk of
radius R 64.0 cm is charged on
one side with a uniform surface
charge density s 7.73 fC/m 2 ,
and then three quadrants of the disk
are removed. The remaining quadrant is shown in Fig. 24-50.
With
V $ 0 at infinity, what is the potential due to the remaining
quad-
rant at point P, which is on the central axis of the original
disk at
distance D $ 25.9 cm from the original center?



We know,

$$V = \int_0^{r} \frac{\sigma r}{2\epsilon_0 \sqrt{r^2+d^2}}\,dr$$

$$= \frac{\sigma}{2\epsilon_0} \sqrt{r^2+d^2}\Big]_0^{R}$$

$$= \frac{\sigma}{\quad} \sqrt{r^2+d^2} - \sqrt{d^2}$$

$$= \frac{6}{2\epsilon_0}\sqrt{r^2+d^2} - \sqrt{d^2}$$

$$= \frac{7.73\times10^{-15}}{2\times8.85\times10^{-12}}\left(\sqrt{(65\times10^{-2})^2+(25.9\times10^{-2})^2} - 25.9\times10^{-2}\right)$$

$$= 192.46\times10^{-6}\ V$$

as 1/4 th remaining

$$= \frac{192.48\times10^{-6}}{} \times \frac{1}{4}$$

$$= 48.116\times10^{-6}\ V$$

(Ans.)

••37 SSM What is the magnitude of the electric field at the point $(3.00\hat{i} - 2.00\hat{j} + 4.00\hat{k})$ m if the electric potential in the region is given by $V = 2.00xyz^2$, where V is in volts and coordinates x, y, and z are in meters?

••37 What is the magnitude of the electric field at the point
if the electric potential in the region is
given by V 2.00xyz2
, where V is in volts and coordinates x, y,
and z are in meters?

$$E\,dr = dV$$

$$E = \frac{dV}{dr}$$

x-axis	y axis	z axis
$E_x = \frac{-dv}{dr_x}$	$E_y = \frac{-dv}{dr_y}$	$E_z = \frac{-dv}{dr_z}$
$E_x = \frac{-d\,2xyz^2}{dx}$	$E_y = \frac{-d\,2xyz^2}{dy}$	$E_z = \frac{-d\,2xyz^2}{dz}$
$= -2yz^2$	$= -2xz^2$	$= -4xyz$

$$x = 3,\ y = -2,\ z = 4$$

$E_x = 64$ $\quad E_y = -96$ $\quad E_z = -96$

$E_x = 64$, $E_y = -96$, $E_z = 96$

$$E = \sqrt{64^2 + (-96)^2 + (96)^2}$$

$$= 150.093 \ N/C$$

•43 SSM ILW WWW How much work is required to set up the arrangement of Fig. 24-52 if $q = 2.30$ pC, $a = 64.0$ cm, and the particles are initially infinitely far apart and at rest?

•44 In Fig. 24-53, seven charged particles are fixed in place to form a square with an edge length of 4.0 cm. How much work must we do to bring a particle of charge $+6e$ initially at rest from an infinite distance to the center of

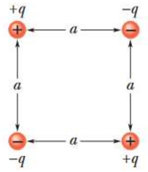
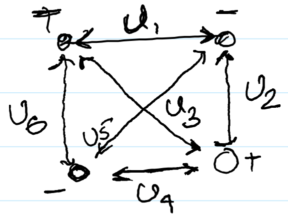


Figure 24-52 Problem 43.

•43 How much work is required to set up the arrangement of Fig. 24-52 if q 2.30 pC, a 64.0 cm, and the particles are initially infinitely far apart and at rest?



We know

$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

$$\Sigma U = \frac{1}{4\pi\epsilon_0}\left(\frac{-q^2}{r} + \frac{-q^2}{r} + \frac{q^2}{\sqrt{2}r} + \frac{-q^2}{r} + \frac{-q^2}{r} + \frac{q^2}{\sqrt{2}r} + \frac{-q^2}{r}\right)$$

$$= \frac{q^2}{4\pi\epsilon_0 r}\left(-4 + \frac{2}{\sqrt{2}}\right)$$

$$= \frac{8.99\times10^{9} \times (2.3\times10^{-12})^2}{64\times10^{-2}}(-2.586)$$

$$= 1.922\times10^{-13} \ (\text{Ans})$$

Chapter- 25

•3 SSM A parallel-plate capacitor has circular plates of 8.20 cm radius and 1.30 mm separation. (a) Calculate the capacitance. (b) Find the charge for a potential difference of 120 V.

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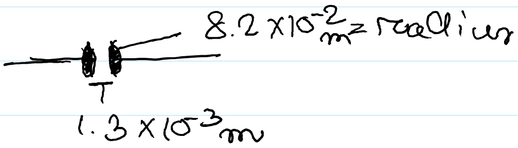
(b) Find the charge for a potential difference of 120 V.



(a)

$$C = \frac{\pi\epsilon_0 R^2}{d}$$

$$= \frac{3.1416\times 8.85\times10^{-12}\times(8.2\times10^{-2})^2}{1.3\times10^{-3}}$$

$$= 1.439\times10^{-10}\,F$$

(b)

We know,

$$C = \frac{q}{V}$$

$$q = CV$$

$$q = 1.439\times10^{-10}\times120\,V$$

$$= 17.268\times10^{-9}\,C$$

•8 How many 1.00 μF capacitors must be connected in parallel to store a charge of 1.00 C with a potential of 110 V across the capacitors?

•8 How many 1.00 mF capacitors must be connected in
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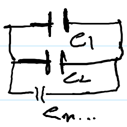
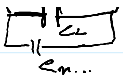
We know



$$C_{eq} = C_1 + C_2 + \ldots + C_n$$

$$= nC \quad [C_1 = C_{\ldots} = C_n]$$



$C_{eq} = C_1 + C_2 + \dots + C_n$

$= nC \quad [C_1 = C_2 ... = C_n]$

So let n parallel to store
le be,

$$nC = \frac{q}{V}$$

$$n = \frac{1.00}{1 \times 10^{-6} \times 110}$$

$$= 9090.909$$

$$\approx 9091 \text{ piece}$$

•10 In Fig. 25-28, find the equivalent capacitance of the combination. Assume that C_1 is 10.0 μF, C_2 is 5.00 μF, and C_3 is 4.00 μF.

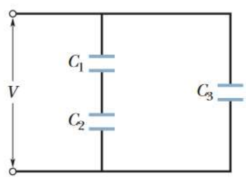


Figure 25-28 Problems 10 and 34.

In Fig. 25-28, find the equiva-
lent capacitance of the combination. Assume that C 1 is 10.0
mF, C 2
is 5.00 mF, and C 3 is 4.00 mF.

$$C_S = (C_1^{-1} + C_2^{-1})^{-1}$$

$$= \left(\frac{1}{10 \times 10^{-6}} + \frac{1}{5 \times 10^{-6}}\right)^{-1}$$

$$= 3.33 \times 10^{-6} F$$

$$C_{eq} = C_S + C_3$$

$$= 7.33 \times 10^{-6} F$$

$C_{eq} = C_S + C_3$

$= 7.33 \times 10^{-6}$ F

••14 GO In Fig. 25-30, the battery has a potential difference of $V = 10.0$ V and the five capacitors each have a capacitance of $10.0\ \mu$F. What is the charge on (a) capacitor 1 and (b) capacitor 2?

••15 GO In Fig. 25-31, a 20.0 V battery is connected across capacitors

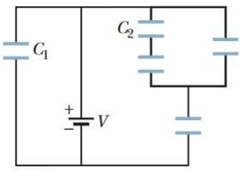
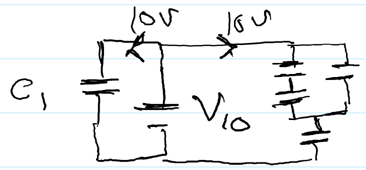


Figure 25-30 Problem 14.

In Fig. 25-30, the battery has
a potential difference of V 10.0 V
and the five capacitors each have a
capacitance of 10.0 mF. What is
the charge on (a) capacitor 1 and
(b) capacitor 2?

(a)

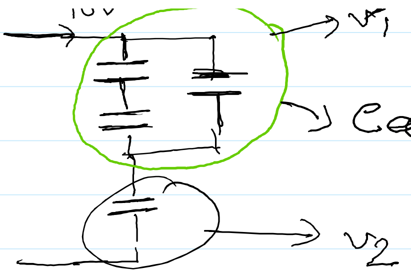


$C_1 V_{10} = Q_1$

$Q = 10 \times 10^{-6} \times 10.0$ V

$= 100 \times 10^{-6}$ V

(b)



$$C_{eq} = 10 + \frac{10 \times 10}{10+10} = 15\ \mu F$$

$$V_1' = \frac{C}{C + C_{eq}} V = \frac{10}{10+15} \times 10 = 4\,V$$

$$V_{C_2} = \frac{C_2}{C_2 + C} = \frac{10}{10+10} \times 4 = 2\,V$$

$$q_2 = C_2 V_{C_2} = 10 \times 10^{-6} \times 2 = 20 \times 10^{-6}\ F \text{ Ans}$$

••21 SSM WWW In Fig. 25-36, the capacitances are $C_1 = 1.0\ \mu F$ and $C_2 = 3.0\ \mu F$, and both capacitors are charged to a potential difference of $V = 100$ V but with opposite polarity as shown. Switches S_1 and S_2 are now closed. (a) What is now the potential difference between points a and b? What now is the charge on capacitor (b) 1 and (c) 2?

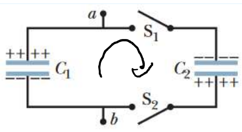


Figure 25-36 Problem 21.

••21 In Fig. 25-36, the
capacitances are C1 1.0 mF and
C2 3.0 mF, and both capacitors are
charged to a potential difference of
V ! 100 V but with opposite polar-
ity as shown. Switches S 1 and S2 are
now closed. (a) What is now the po-
tential difference between points a and b? What now is the
charge
on capacitor (b) 1 and (c) 2?

(a)

$$Q_1 = C_1 V = 1\ \mu F \times 100 = 1 \times 10^{-4}\ F$$

$$Q_2 = C_2 V = 3\ \mu F \times 100 = 3 \times 10^{-4}\ F$$

$$Q_{sum} = 1 \times 10^{-4} - 3 \times 10^{-4} = -2 \times 10^{-4}\ F$$

$$C_{eq} = 1 \times 10^{-6} + 3 \times 10^{-6} = 4 \times 10^{-6}\ F$$

$$V' = \frac{Q}{C} = \frac{-2 \times 10^{-4}}{4 \times 10^{-6}} = -50\ V = 50\ V$$

(Ans)

(b)

After connection,

$$Q_{sum} = Q_1' = Q_2'$$

So,

$$Q_1' = C_1 V' = 1\times10^{-6}\times 50 = 50\times10^{-6}\, C$$

So, $Q_2' = C_2 V' = 3\times10^{-6}\times 50 = 150\times10^{-6} C$

•31 SSM A 2.0 μF capacitor and a 4.0 μF capacitor are connected in parallel across a 300 V potential difference. Calculate the total energy stored in the capacitors.

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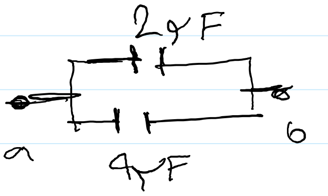
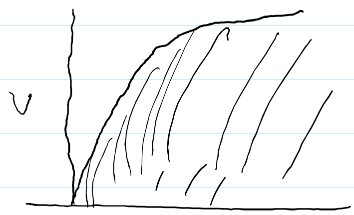


$$V_{ab} = 300\,V$$

$$C_{eq} = (2+4)\times10^{-6}$$

$$= 6\times10^{-6}\,F$$

$$V = V_0(1-e^{-t/RC})$$



$$U = \int$$

$$U = \int_0^q v\,dq$$

$$= \frac{1}{C}\int_0^q q\,dq$$

$$U = \frac{1}{2}\frac{Q^2}{C}$$

$$= \frac{1}{2}\frac{\cancel{C^2}V^2}{\cancel{C}}$$

$$= \frac{1}{2}CV^2$$

$$= \frac{1}{2}\times6\times10^{-6}\times300^2$$

$$= 0.27\,J$$

$$= \frac{1}{2C} q^2$$

•41 SSM A coaxial cable used in a transmission line has an inner radius of 0.10 mm and an outer radius of 0.60 mm. Calculate the capacitance per meter for the cable. Assume that the space between the conductors is filled with polystyrene.

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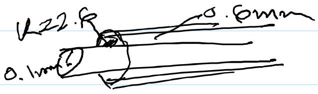
the
capacitance per meter for the cable. Assume that the space between the conductors is filled with polystyrene.



$$\frac{C}{L} = \frac{2\pi \epsilon_0 k}{\ln\left(\frac{b}{a}\right)}$$

$$= \frac{2\pi \times 8.85 \times 10^{-12} \times 2.6}{\ln\left(\frac{0.6}{0.1}\right)}$$

$$= 8.1 \times 10^{-11} \frac{F}{L}$$

••50 GO Figure 25-49 shows a parallel-plate capacitor of plate area $A = 10.5$ cm^2 and plate separation $2d = 7.12$ mm. The left half of the gap is filled with material of dielectric constant $\kappa_1 = 21.0$; the top of the right half is filled with material of dielectric constant $\kappa_2 = 42.0$; the bottom of the right half is filled with material of dielectric constant $\kappa_3 = 58.0$. What is the capacitance?

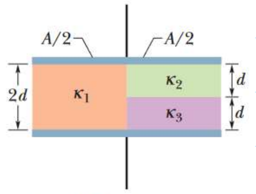


Figure 25-49 Problem 50.

Figure 25-49 shows a parallel-
plate capacitor of plate area A ! 10.5
cm2 and plate separation 2d ! 7.12 mm.
The left half of the gap is filled with ma-
terial of dielectric constant k1 ! 21.0;
the top of the right half is filled with ma-
terial of dielectric constant k2 ! 42.0;
the bottom of the right half is filled
with material of dielectric constant k3 !
58.0.What is the capacitance?

we know,

$$C = \frac{\varepsilon_0 A k}{d}$$

$$C_1 = \frac{\varepsilon_0 \frac{A}{2} k_1}{2d} = \frac{\varepsilon A k_1}{4d}$$

$$C_2 = \frac{\varepsilon \frac{A}{2} k_2}{d} = \frac{\varepsilon A k_2}{2d} \quad \Big| \quad C_3 = \frac{\varepsilon A k_3}{2d}$$

$$C_{eq} = C_1 + \frac{C_2 \times C_3}{C_2 + C_3}$$

$$= \frac{\varepsilon_0 A k_1}{4d} + \frac{\frac{\varepsilon_0 A k_2}{2} \cdot \frac{\varepsilon_0 A k_3}{2}}{\frac{\varepsilon_0 A}{2}(k_2 + k_3)}$$

$$= \frac{\varepsilon_0 A}{4d}\left(k_1 + \frac{2 k_2 k_3}{k_2 + k_3}\right)$$

$$= \frac{8.85 \times 10^{-12} \times 10.5 \times 10^{-3}}{4 \frac{7.12 \times 10^{-3}}{2}}\left(21 + \frac{2 \times 41 \times 58}{41 + 58}\right)$$

$$= 4.507 \times 10^{-11} \text{ F}$$

•5 SSM WWW A beam contains 2.0×10^8 doubly charged positive ions per cubic centimeter, all of which are moving north with a speed of 1.0×10^5 m/s. What are the (a) magnitude and (b) direction of the current density $\vec{J}$? (c) What additional quantity do you need to calculate the total current i in this ion beam?

•5 A beam contains 2.0 $ 10 8 doubly charged posi-
tive ions per cubic centimeter, all of which are moving north
with
a speed of 1.0 $ 10 5 m/s. What are the (a) magnitude and
(b) direc-
tion of the current density (c) What additional quantity do
you
need to calculate the total current i in this ion beam?

we know

current density $J = nqV_d$

$V_d = 1 \times 10^5 \, ms^{-1}$

$n = 2.0 \times 10^8 \, cm^{-3}$

$= 2 \times 10^{14} \, m^{-3}$

doubly charged meam 2e

$q = 2 \times 1.602 \times 10^{-19}$

$q = 3.204 \times 10^{-19} \, C$

(a)

we kown

$J = nqV_d = 1 \times 10^5 \times 3.204 \times 10^{-19} \times 2 \times 10^{14}$

$= 6.408 \, \frac{A}{m^2}$ (Ans.)

(b)

as stated in question the charges are moving Northly

(c)

The crossesection area of beam is needed

•19 SSM What is the resistivity of a wire of 1.0 mm diameter, 2.0 m length, and 50 mΩ resistance?

•19 What is the resistivity of a wire of 1.0 mm diameter,
2.0 m
length, and 50 m resistance?

we know,

$$\rho = \frac{RA}{L} \quad \left[\because A = \pi r^2\right]$$

$$= \frac{50\times10^{-3} \times \pi \times \left(\frac{1\times10^{-3}}{2}\right)^2}{2}$$

$$= 19.64\times10^{-9}\ \Omega\cdot m$$

(Ans.)

••25 SSM ILW A wire with a resistance of 6.0 Ω is drawn out through a die so that its new length is three times its original length. Find the resistance of the longer wire, assuming that the resistivity and density of the material are unchanged.

••25 A wire with a resistance of 6.0 0 is drawn out
through a die so that its new length is three times its
original
length. Find the resistance of the longer wire, assuming that
the re-
sistivity and density of the material are unchanged.

$$\frac{A'}{L'} = \frac{\frac{A_0}{3}}{3L_0} \qquad \left[\rho = \frac{RA}{L}\right.$$

$$\frac{A'}{L'} = \frac{A_0}{9L_0}$$

$$\frac{L'}{A'} = \frac{9L_0}{A_0}$$

We known,

before

$$R_0 = \frac{\rho L_0}{A_0}$$

After

$$R' = \frac{\rho L'}{A'} = \frac{9\rho L_0}{A_0}$$

$$\frac{R'}{R_0} = \frac{\frac{9\rho L_0}{A_0}}{\frac{\rho L_0}{A_0}} = 9$$

$R' = 9R_0$ (Ans.)

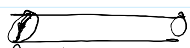
••27 SSM WWW Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1.0 mm. Conductor B is a hollow tube of outside diameter 2.0 mm and inside diameter 1.0 mm. What is the resistance ratio R_A/R_B, measured between their ends?

••27 Two conductors are made of the same material
and have the same length. Conductor A is a solid wire of
diameter
1.0 mm. Conductor B is a hollow tube of outside diameter 2.0
mm
and inside diameter 1.0 mm. What is the resistance ratio R
A/RB,
measured between their ends?

both have same

$\rho = \rho = \rho$ $\quad \left[\rho = \frac{RA}{L} \right.$

$L = L = L$



$d = 1\,mm$

$r_1 = 0.5 \times 10^{-3}\,m$

$A_A = \pi r^2$

$= \pi \times 250 \times 10^{-9}$

$d_{out} = 2.0\,mm$

$r_{in} = 0.5 \times 10^{-3}\,m$

$r_{out} = 1 \times 10^{-3}\,m$

$A_B = A_{out} - A_{in}$

$= \pi\left((1\times10^{-3})^2 - (0.5\times10^{-3})^2\right)$

$= 750 \times 10^{-9}\,\pi$

$= \pi \times 250 \times 10^{-9}$ | $= \pi ((1 \times 10^{-3}) - (0.5 \times 10^{-3}))$

$= 750 \times 10^{-9} \pi$

$$\frac{R_A}{R_B} = \frac{\frac{\rho L}{A_A}}{\frac{\rho L}{A_B}}$$

$$\frac{R_A}{R_B} = \frac{A_B}{A_A} = \frac{\cancel{\pi}\, 750 \times 10^{-9}}{\cancel{\pi}\, 250 \times 10^{-9}}$$

$$\frac{R_A}{R_B} = 3$$

(Ans.)

•41 SSM A 120 V potential difference is applied to a space heater whose resistance is 14 Ω when hot. (a) At what rate is electrical energy transferred to thermal energy? (b) What is the cost for 5.0 h at US$0.05/kW · h?

•41 A 120 V potential difference is applied to a space heater
whose resistance is 14 when hot. (a) At what rate is
electrical en-
ergy transferred to thermal energy? (b) What is the cost
for 5.0 h at
US$0.05/kW &h?

(a)

We know,

$$P = IV = \frac{V}{R} V \quad [V = IR]$$

$$= \frac{V^2}{R} = \frac{120^2}{14} = 1028.57 \, W$$

(b)

$1 \, h = 1028.57 \, W$

$5 \, h = 5 \times 1028.57 \, W$

$= 5142.85 \, W = 5.14285 \, kW$

Cost $= 5.14285 \times 0.05$

$= 0.2571$ \$

71 SSM (a) At what temperature would the resistance of a copper conductor be double its resistance at 20.0°C? (Use 20.0°C as the reference point in Eq. 26-17; compare your answer with Fig. 26-10.) (b) Does this same "doubling temperature" hold for all copper conductors, regardless of shape or size?

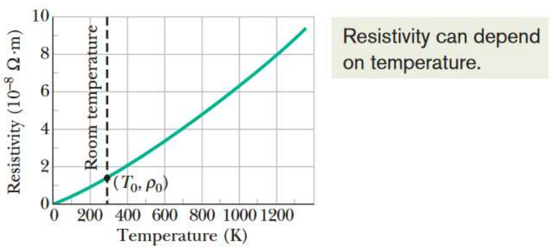


Figure 26-10 The resistivity of copper as a function of temperature. The dot on the curve marks a convenient reference point at temperature $T_0 = 293$ K and resistivity $\rho_0 = 1.69 \times 10^{-8}\ \Omega\cdot$m.

71 (a) At what temperature would the resistance of a cop-
per conductor be double its resistance at 20.0 C? (Use 20.0
C as
the reference point in Eq. 26-17; compare your answer with
Fig. 26-10.) (b) Does this same "doubling temperature" hold
for all
copper conductors, regardless of shape or size?

(a)

we know,

$$T = T_0 + \frac{1}{\alpha}$$

$$= 20 + \frac{1}{\alpha}$$

we know

$\alpha = 4.3 \times 10^{-1}$ K

$$= 20 + \frac{1}{4.3\times10^{-3}}$$

$$= 252.558\,^{\circ}C$$

(b)

for all size and shape it would hold unless its different unit.

Chapter 27: Circuits

Module 27-1 Single-Loop Circuits

•1 SSM WWW In Fig. 27-25, the ideal batteries have emfs $\mathscr{E}_1 = 12$ V and $\mathscr{E}_2 = 6.0$ V. What are (a) the current, the dissipation rate in (b) resistor 1 (4.0 Ω) and (c) resistor 2 (8.0 Ω), and the energy transfer rate in (d) battery 1 and (e) battery 2? Is energy being supplied or absorbed by (f) battery 1 and (g) battery 2?

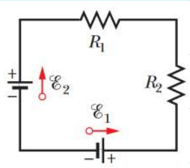
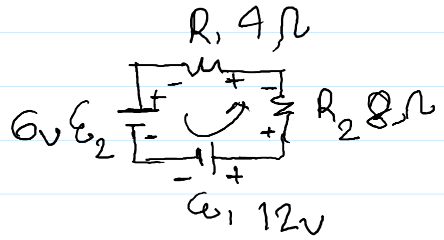


Figure 27-25 Problem 1.

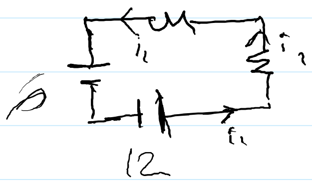
. . .

•1 In Fig. 27-25, the ideal batteries have emfs V and V. What are (a) the current, the dissipation rate in (b) resistor 1 (4.0) and (c) resistor 2 (8.0 0), and the energy transfer rate in (d) battery 1 and (e) battery 2? Is energy being supplied or absorbed by (f) battery 1 and (g) battery 2?



(a)

$$12 - 8i_1 - 4i_1 - 6 = 0$$



(e)

$$P = IV = 0.5 \times 12$$
$$= 6 \text{ watt}$$

$6 - 12 i_1 = 0$

$i_1 = \frac{12}{6} = 0.5 A$

(b)

$P = VI = I^2 R$ [we know, $V = IR$]

$= (0.5)^2 \times 4$

$= 1$ watt

(c)

$P = I^2 R = (0.5)^2 \times 8$

$= 2$ watt

(d)

$P = IV = 0.5 \times 6$

$= 3$ watt

(f)

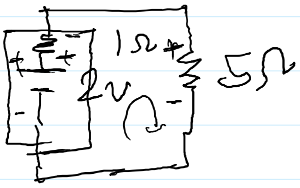
12V has higher emf and has same current and voltage direction making it discharging

(g)

6V has lower emf and oposite to current flow making the battery charging.

•7 A wire of resistance 5.0 Ω is connected to a battery whose emf ℰ is 2.0 V and whose internal resistance is 1.0 Ω. In 2.0 min, how much energy is (a) transferred from chemical form in the battery, (b) dissipated as thermal energy in the wire, and (c) dissipated as thermal energy in the battery?

•7 A wire of resistance 5.0 0 is connected to a battery
whose emf
is 2.0 V and whose internal resistance is 1.0 0. In 2.0
min, how
much energy is (a) transferred from chemical form in
the battery,
(b) dissipated as thermal energy in the wire, and (c)
dissipated as
thermal energy in the battery?



(a)

$R_{eq} = 1 + 5$

$= 6 \Omega$

$P = IV = \frac{V^2}{R_{eq}} = \frac{2^2}{6}$

$= 0.667$ watt

2min

$2 - 1i - 5i = 0$

$6i = 2$

$i = \frac{1}{3}$

$$U = Pt = 0.667 \times 2 \times 60$$
$$= 80 \text{ J}$$

(b)

$$U_w = Pt = IV \cdot t = I^2Rt = \left(\frac{1}{3}\right)^2 \times 5 \times 2 \times 60$$
$$\approx 66.67 \text{ J}$$

(c)

$$U_i = Pt = I^2Rt = \left(\frac{1}{3}\right)^2 \times 1 \times 2 \times 60$$
$$= 13.33 \text{ J}$$

•••17 SSM In Fig. 27-33, battery 1 has emf $\mathscr{E}_1 = 12.0$ V and internal resistance $r_1 = 0.016\ \Omega$ and battery 2 has emf $\mathscr{E}_2 = 12.0$ V and internal resistance $r_2 = 0.012\ \Omega$. The batteries are connected in series with an external resistance R. (a) What R value makes the terminal-to-terminal potential difference of one of the batteries zero? (b) Which battery is that?

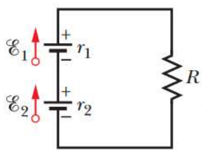


Figure 27-33 Problem 17.

•••17 In Fig. 27-33, battery 1 has emf V and internal resistance r1 0.016 and battery 2 has emf V and internal resistance r2 0.012 . The batteries are connected in series with an external resistance R. (a) What R value makes the terminal-to-terminal potential difference of one of the batteries zero? (b) Which battery is that?

(a)

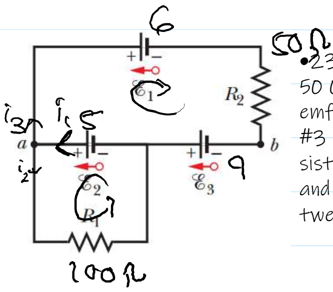
$$R\mathcal{E}_1 = \mathcal{E}_2 r_1 - \mathcal{E}_2 r_2$$
$$R = \frac{12(0.016 - 0.012)}{12}$$
$$R = 0.004\ \Omega$$

(b)

This would occour to the first battery.

•23 In Fig. 27-35, $R_1 = 100\ \Omega$, $R_2 = 50\ \Omega$, and the ideal batteries have emfs $\mathscr{E}_1 = 6.0$ V, $\mathscr{E}_2 = 5.0$ V, and $\mathscr{E}_3 = 4.0$ V. Find (a) the current in resistor 1, (b) the current in resistor 2, and (c) the potential difference between points a and b.

•24 In Fig. 27-36, $R_1 = R_2 = 4.00\ \Omega$



•23 In Fig. 27-35, R1 ! 100 0, R2 ! 50 0, and the ideal batteries have emfs #1 ! 6.0 V, #2 ! 5.0 V, and #3 ! 4.0 V. Find (a) the current in resistor 1, (b) the current in resistor 2, and (c) the potential difference between points a and b.

(a)

$$5 - 100 i_2 = 0$$

$$i_2 = \frac{5}{100}$$

$$i_2 = 0.05\ A$$

(b)

$$4 + 5 - 6 - 50 i_3 = 0$$

$$3 - 50 i_3 = 0$$

$$i_3 = \frac{3}{50}$$

$$i_3 = 0.06\ A$$

(c)

$$V_a - 5 - 4 - V_b = 0$$

$$V_a - V_b = 9$$

$$\Delta V_{ab} = 9 \text{ (Ans)}$$

••31 SSM GO In Fig. 27-42, the ideal batteries have emfs $\mathscr{E}_1 = 5.0$ V and $\mathscr{E}_2 = 12$ V, the resistances are each 2.0 Ω, and the potential is defined to be zero at the grounded point of the circuit. What are potentials (a) V_1 and (b) V_2 at the indicated points?

••32 Both batteries in Fig. 27-43*a* are ideal. Emf $\mathscr{E}_1$ of battery 1 has a fixed value, but emf $\mathscr{E}_2$ of battery 2 can be varied between 1.0 V and 10 V. The plots in Fig. 27-43*b* give the currents through the two batteries as a function of $\mathscr{E}_2$. The vertical scale is

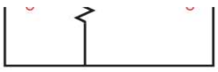


Figure 27-41 Problems 30, 41, and 88.

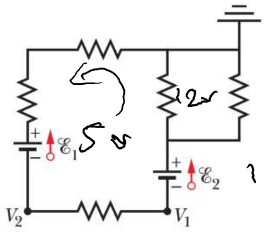


Figure 27-42 Problem 31.

••31 In Fig. 27-42, the ideal batteries have emfs 1 5.0 V and V, the resistances are each 2.0 , and the potential is defined to be zero at the grounded point of the circuit. What are potentials (a) V1 and (b) V2 at the indicated points?

12v

12v

$$R_p = \frac{2\times 2}{2+2} = 1\,\Omega$$

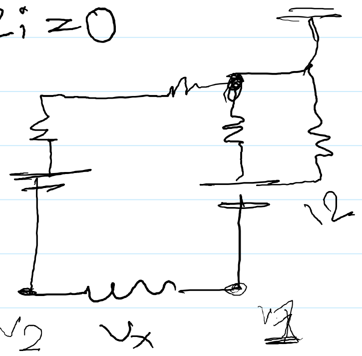
$$R_{eq} = 2+2+1 \cancel{+2} = 7\,\Omega$$

$$12 - 1i_i - 2i - 2i - 5 - 2i = 0$$

$$7 - 7i = 0$$

$$7i = 7$$

$$i = 1\ A$$



(b)

$$V_x = IR$$

$$= 1\times 2 = 2V$$

(Ans.)

(a) $V_1 = (2V) - 12 = -11$ V

R_p

••36 In Fig. 27-47, $\mathscr{E}_1 = 6.00$ V, $\mathscr{E}_2 = 12.0$ V, $R_1 = 100\ \Omega$, $R_2 = 200\ \Omega$, and $R_3 = 300\ \Omega$. One point of the circuit is grounded ($V = 0$). What are the (a) size and (b) direction (up or down) of the current through resistance 1, the (c) size and (d) direction (left or right) of the current through resistance 2, and the (e) size and (f) direction of the current through resistance 3? (g) What is the electric potential at point A?

Figure 27-46 Problem 35.

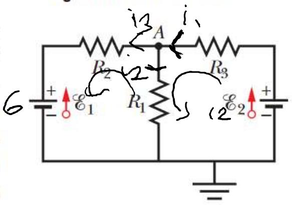


Figure 27-47 Problem 36.

••36 In Fig. 27-47, V, V, R1 100 , and R3 300 . One point of the circuit is grounded (V ! 0). What are the (a) size and (b) direction (up or down) of the current through resistance 1, the (c) size and (d) direction (left or right) of the current through resistance 2, and the (e) size and (f) direction of the current through resistance 3? (g) What is the electric potential at point A?

$i_1 = i_2 + i_3$

$i_3 = i_1 - i_2$

loop-1

$12 - 300 i_1 - 100 i_2 = 0$

$300 i_1 + 100 i_2 = 12$ — (1)

Loop-2

$-200(i_1 - i_2) - 6 + 100 i_2 = 0$

$-200 i_1 + 200 i_2 + 100 i_2 = 6$

$-200 i_1 + 300 i_2 = 6$ — (2)

$i_1 = 0.0273$ A

$i_2 = 0.0382$ A

(a) $i_2 = 0.0382$ A

(b) downward ↓

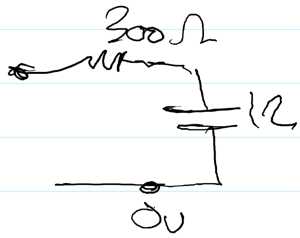
(c) $i_3 = |0.0273 - 0.0382|$

$= 0.109$ A

(d) right →

(e) $i_1 = 0.0273$ A

(f) left ←



(g) $V_1 = R_3 \times i_1 = 300 \times 0.0273$

$= 8.19$ V

$V_1' = 12 - 8.19 = 3.81$ V (Ans.)

Module 27-4 ***RC* Circuits**

•**57** Switch S in Fig. 27-63 is closed at time $t = 0$, to begin charging an initially uncharged capacitor of capacitance $C = 15.0\ \mu F$ through a resistor of resistance $R = 20.0\ \Omega$. At what time is the potential across the capacitor equal to that across the resistor?

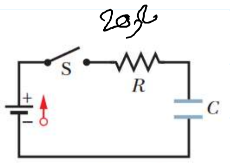


Figure 27-63 Problems 57 and 96.

•57 Switch S in Fig. 27-63 is closed at time t ! 0, to begin charging an initially uncharged capacitor of capacitance C ! 15.0 mF through a resistor of resistance R! 20.0 0. At what time is the potential across the capacitor equal to that across the resistor?

We know,

$t = RC\ln(2)$

$= 20 \times 15 \times 10^{-6} \ln(2)$

$= 207.944 \times 10^{-6}$ s

••63 SSM WWW In the circuit of Fig. 27-65, $\mathscr{E} = 1.2$ kV, $C = 6.5\ \mu F$, $R_1 = R_2 = R_3 = 0.73\ M\Omega$. With C completely uncharged, switch S is suddenly closed (at $t = 0$). At $t = 0$, what are (a) current i_1 in resistor 1, (b) current i_2 in resistor 2, and (c) current i_3 in resistor 3? At $t = \infty$ (that is, after many time constants), what are (d) i_1, (e) i_2, and (f) i_3? What is the potential difference V_2 across resistor 2 at (g) $t = 0$ and (h) $t = \infty$? (i) Sketch V_2 versus t between these two extreme times.

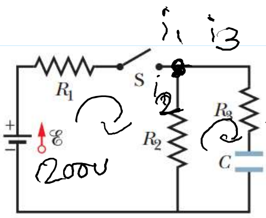


Figure 27-65 Problem 63.

••63 In the circuit of Fig.
27-65, kV, C 6.5 mF, R1 !
R2 ! R3 ! 0.73 MΩ. With C completely
uncharged, switch S is suddenly closed
(at t ! 0). At t ! 0, what are (a) current
i1 in resistor 1, (b) current i2 in resistor 2,
and (c) current i3 in resistor 3? At t ! ,
(that is, after many time constants),
!# ! 1.2
what are (d) i1, (e) i2, and (f) i3 ? What is the
potential difference V2
across resistor 2 at (g) t ! 0 and (h) t ! ,? (i) Sketch
V2 versus t be-
tween these two extreme times.

$$1200 - 0.73\times10^6 i_1 - 0.73\times10^6 i_2 = 0$$

$$0.73\times10^6 i_1 + 0.73\times10^6 i_2 = 1200 \quad \text{— (i)}$$

$$i_1 = i_2 + i_3$$

$$i_3 = i_1 - i_2$$

$$+0.73\times10^6 i_2 - 0.73\times10^6 (i_1 - i_2) = 0$$

$$+0.73\times10^{+6} i_2 - 0.73\times10^6 i_1 + 0.73\times10^6 i_2 = 0$$

$$-0.73\times10^6 i_1 + 1.46\times10^6 i_2 = 0 \quad \text{— (ii)}$$

$$i_1 = 0.001096\ A = 1.1\times10^{-3}\ A$$

$$i_2 = 0.000548\ A = 5.5\times10^{-4}\ A$$

(a)

$$i_1 = 1.1\times10^{-3}\ A \text{ (Ans)}$$

(b)

$$i_2 = 5.5\times10^{-4}\ A \text{ (Ans)}$$

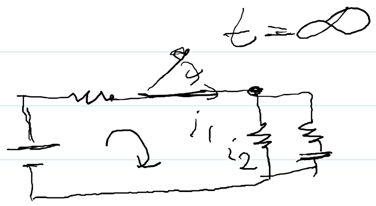
$i_2 = 5.5\times10^{-4}\,A$ (Ans)

(c)

$i_3 = i_1 - i_2 = 1.1\times10^{-3} - 5.5\times10^{-4}$

$= 560\times10^{-6}\,A$ (Ans)

(d)



$i_1 = i_2$

$i_1 = i_2$

$1200 - 0.73\times10^{6}\, i_1 - 0.73\times10^{6}\, i_2 = 0$

$1200 - 1.46\times10^{6}\, i_1 = 0$

$i_1 = 821.917\times10^{-6}\,A$ (Ans)

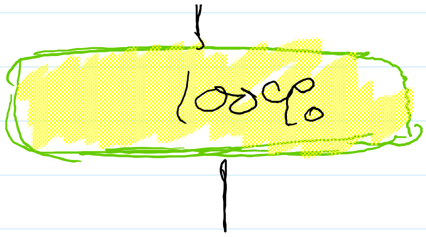
(e)

$i_2 = 821.917\times10^{-6}\,A$ (Ans)

(f)

$i_3 = 0$ As chapasitor is fully charged

lower



no more flow

(g)

at R_2 $t=0$

$$R_{eq} = R_1 + (R_2 // R_3)$$

$$= 0.73\times10^{6} + \left(0.73\times10^{6^{-1}} + 0.73\times10^{6^{-1}}\right)^{-1}$$

$$= 1095\times10^{3}$$

$$V_R = \frac{R_2 // R_3}{1095\times10^{3}} 1200$$

$V_2 = 400V$ (Ans)

(h)

at $t=\infty$

$R_2 \Rightarrow$

$$R_{eq} = R_1 + R_2$$

$$= 1.46\times10^{6}$$

$= 1.46 \times 10^{6}$

$V_2 = \frac{R_2}{1.46 \times 10^{6}} \times 1200$

$= 600\,V$

g

as its an expontial expention