Find the total resistance and current $I$ for the circuit.

$$E = 60 \text{ V}$$

Answer

20$\Omega$
3 A

Find the total resistance and current $I$ for the circuit.

$$E = 120 \text{ V}$$

Answer

10 k$\Omega$
12 mA

Find the total resistance and current $I$ for the circuit.

Answer

1.63 M$\Omega$
6.135 $\mu$A

Find the total resistance and current $I$ for the circuit.

Answer

110 $\Omega$
12 mA

Find the total resistance and current $I$ for the circuit.

Answer

2 k$\Omega$
For the circuit show the total resistance is defined. Find the unknown resistance and the current in the circuit.

\[ R_T = 220 \, \Omega \]
\[ R_2 = R_1 = 10 \, \Omega \]

**Answer**

50 \, \Omega
0.5455

Find the applied voltage \( E \) necessary to develop the current specified in the network.

\[ I = 240 \, mA \]

**Answer**

6.5 \, \Omega
1.56 \, V

For the circuit show the total resistance is defined. Find the unknown resistance and the current in the circuit.

\[ R_T = 1.6 \, M\Omega \]
\[ R = 100 \, k\Omega \]
\[ E = 50 \, V \]
\[ R_1 = 0.2 \, M\Omega \]
\[ R_2 = 0.56 \, k\Omega \]

**Answer**

1.244 \, M\Omega
31.25 \, \mu A

Find the applied voltage \( E \) necessary to develop the current specified in the network.

\[ I = 4 \, mA \]

**Answer**

4 \, k\Omega
16 \, V

For the network, determine the current \( I \), the unknown resistance, and the voltage across each element.

\[ R_T = 16 \, \Omega \]
\[ E = 12 \, V \]
\[ V(5 \, \Omega) = 30 \, V \]
\[ V(9 \, \Omega) = 54 \, V \]
\[ E = 96 \, V \]
For the network, determine the current $I$, the unknown resistance, and the voltage across each element.

\[
\begin{align*}
P &= 144 \text{ mW} \\
E &= 40 \text{ V} \\
R &= 1 \text{ k}\Omega \\
I &= \frac{E}{R} = \frac{40 \text{ V}}{1 \text{ k}\Omega} = 40 \text{ mA} \\
\end{align*}
\]

**Answer**

$A = 6 \text{ mA}$

**R** $= 1.67 \text{ k}\Omega$

$V(1\text{k}\Omega) = 6 \text{ V}$

$V(4\text{k}\Omega) = 24 \text{ V}$

14 Determine the current $I$ and its direction for the shown network. Before solving for $I$, redraw the network with a single voltage source.

\[
\begin{align*}
E &= 18 \text{ V} \\
I &= \frac{E}{R} = \frac{18 \text{ V}}{4.7 \text{ k}\Omega} = 3.83 \text{ mA} \\
\end{align*}
\]

**Answer**

2.087 A (counterclockwise)

15 Find the unknown voltage source and resistor for the network shown. Also indicate the direction of the resulting current.

\[
\begin{align*}
I &= 5 \text{ mA} \\
P &= 100 \text{ mW} \\
\end{align*}
\]

**Answer**

4 k\Omega

$E = 45 \text{ Volts}$

$R = 25 \text{ volts}$
16 Find the unknown voltage source and resistor for the network shown. Also indicate the direction of the resulting current.

Answer

\[ I = 8 \text{ mA} \]
\[ R = 1.5 \text{ k}\Omega \]
\[ E = 42 \text{ V} \]

17 Find \( V_{ab} \) with polarity for the circuits of the figure. Each box can contain a load or power supply, or a combination of both.

Answer

5 V

18 Find \( V_{ab} \) with polarity for the circuits of the figure. Each box can contain a load or power supply, or a combination of both.

Answer

70 V

19 Although the network shown is not a simple series circuit, determine the unknown voltages using Kirchoff’s voltage law.

Answer

4 V

20 Although the network shown is not a simple series circuit, determine the unknown voltages using Kirchoff’s voltage law.

Answer

16 V

21 Determine the current \( I \) and the Voltage \( V_1 \) for the network shown.

Answer

3.28 mA
For the circuit shown in the figure
(a) Find the total resistance, current, and unknown voltage drops.
(b) Verify Kirchhoff's voltage law around the closed loop.
(c) Find the power dissipated by each resistor, and note whether the power delivered is equal to the power dissipated.
(d) If the resistors are available with wattage ratings of 1/2, 1, and 2 W, what minimum wattage rating can be used for each resistor in this circuit?

\[ \text{Answer} \]

(a) \( R_T = 6 \, \text{k}\Omega \)
\( I = 20 \, \text{mA} \)
\( V1 = 60 \, \text{V} \)
\( V2 = 20 \, \text{V} \)
\( V3 = 40 \, \text{V} \)
(b) \( E = 120 \, \text{V} \)
(c) \( P1 = 1.2 \, \text{W} \)
\( P2 = 0.4 \, \text{W} \)
\( P3 = 0.8 \, \text{W} \)
\( P_{del} = 2.4 \, \text{W} \)
(d) \( R1 = 2 \, \text{W} \)
\( R2 = 1/2 \, \text{W} \)
\( R3 = 1 \, \text{W} \)

Find the unknown quantities in the circuits of the figure using the information provided.

\[ \text{Answer} \]

For the circuit shown in the figure
(a) Find the total resistance, current, and unknown voltage drops.
(b) Verify Kirchhoff's voltage law around the closed loop.
(c) Find the power dissipated by each resistor, and note whether the power delivered is equal to the power dissipated.
(d) If the resistors are available with wattage ratings of 1/2, 1, and 2 W, what minimum wattage rating can be used for each resistor in this circuit?

\[ \text{Answer} \]

Find the unknown quantities in the circuits of the figure using the information provided.

\[ \text{Answer} \]
27. Find the unknown quantities in the circuits of the figure using the information provided.

\[ P = 8 \, \text{W} \]
\[ R_T = 16 \, \Omega \]

\[ E \]

\[ I \]

Answer

28. Eight holiday lights are connected in series as shown in the figure.
(a) If the set is connected to a 120-V source, what is the current through the bulbs if each bulb has an internal resistance of 28 \( 1/8 \, \Omega \)?
(b) Determine the power delivered to each bulb.
(c) Calculate the voltage drop across each bulb.
(d) If one bulb burns out (that is, the filament opens), what is the effect on the remaining bulbs?

Answer

29. Using the voltage divider rule, find \( V_{ab} \) (with polarity) the circuits of the figure.

\[ 100 \, \text{V} \]

\[ 25 \, \Omega \]

\[ 50 \, \Omega \]

\[ V_{ab} \]

Answer

30. Using the voltage divider rule, find \( V_{ab} \) (with polarity) the circuits of the figure.

\[ 80 \, \text{V} \]

\[ 20 \, \Omega \]

\[ 10 \, \Omega \]

\[ 4 \, \Omega \]

\[ 6 \, \Omega \]

Answer

31. Using the voltage divider rule, find \( V_{ab} \) (with polarity) the circuits of the figure.

\[ 40 \, \text{V} \]

\[ 4 \, \text{k}\Omega \]

\[ 1 \, \text{k}\Omega \]

\[ 2 \, \text{k}\Omega \]

\[ 3 \, \text{k}\Omega \]

Answer
Using the voltage divider rule, find $V_{ab}$ (with polarity) for the circuits of the figure.

![Circuit diagram](image)

Answer

Find the unknown resistance using the voltage divider and the information provided for the circuits of the figure.

![Circuit diagram](image)

Answer

Find the unknown resistance using the voltage divider and the information provided for the circuits of the figure.

![Circuit diagram](image)

Answer

If two identical resistors are connected in series to a battery, does the battery have to supply more power or less power than when only one of the resistors is connected? Explain.

Answer

Answer the following questions:
(a) For what use are batteries connected in series?
(b) For what use are they connected in parallel?
(c) Does it matter if the batteries are nearly identical or not in either case?

Answer

Answer the following questions:
(a) Calculate the terminal voltage for a battery with an internal resistance of 0.900 Ω and an emf of 8.50 V when the battery is connected in series with an 81.0 Ω resistor.
(b) Calculate the terminal voltage for a battery with an internal resistance of 0.900 Ω and an emf of 8.50 V when the battery is connected in series with an 810 Ω resistor.

Answer

(a) 8.41 V
(b) 8.49 V

Four 1.5-V cells are connected in series to a 12 Ω light bulbs. If the resulting current is 0.45 A, what is the internal resistance of each cell, assuming they are identical and neglecting the wires?

Answer

0.33 Ω

Answer the following questions:
(a) What is the internal resistance of a 12.0-V car battery whose terminal voltage drops to 8.4 V when the starter draws 75 A?
(b) What is the resistance of the starter?

Answer

(a) 0.048 Ω
(b) 0.11 Ω
40 A 1.5-V dry cell can be tested by connecting it to a low resistance ammeter. It should be able to supply at least 22 A. What is the internal resistance of the cell in this case, assuming it is much greater than that of the ammeter?

**Answer**

0.068 Ω

41 A battery produces 40.8 V when 7.40 A is drawn from it and 47.3 V when 2.20 A is drawn. What are the emf and internal resistance of the battery?

**Answer**

1.25 Ω
50.1 V

42 A battery has an emf of 15.0 V. The terminal voltage of the battery is 11.6 V when it is delivering 20.0 W of power to an external load resistor R. (a) What is the value of R? (b) What is the internal resistance of the battery?

**Answers**

(a) 6.73 Ω
(b) 1.97 Ω

43 Answer the following questions. (a) What is the current in a 5.60 Ω resistor connected to a battery that has a 0.200 Ω internal resistance if the terminal voltage of the battery is 10.0 V? (b) What is the emf of the battery?

**Answers**

(a) 1.79 A
(b) 10.4 V

44 Two 1.50 V batteries—with their positive terminals in the same direction—are inserted in series into the barrel of a flashlight. One battery has an internal resistance of 0.255 Ω, the other an internal resistance of 0.153 Ω. When the switch is closed, a current of 600 mA occurs in the lamp. (a) What is the lamp’s resistance? (b) What fraction of the chemical energy transformed appears as internal energy in the batteries?

**Answers**

(a) 4.59 Ω
(b) 8.16 %

45 An automobile battery has an emf of 12.6 V and an internal resistance of 0.080 Ω. The headlights together present equivalent resistance 5.00 Ω (assumed constant). (a) What is the potential difference across the headlight bulbs when they are the only load on the battery? (b) What is the potential difference across the headlight bulbs when the starter motor is operated, taking an additional 35.0 A from the battery?

**Answers**

(a) 12.4 V
(b) 9.65 V

46 A battery has an emf of 9.20 V and an internal resistance of 1.20 Ω. (a) What resistance across the battery will extract from it a power of 12.8 W? (b) What resistance across the battery will extract from it a power of 21.2 W?

**Answers**

(a) 3.84 Ω or 0.375 Ω
(b) there is no resistance

47 The figure shows the current i in a single-loop circuit with a battery B and a resistance R (and wires of negligible resistance). (a) Should the emf arrow at B be drawn pointing leftward or rightward? (b) At points a, b, and c, rank the magnitude of the current, greatest first. (c) At points a, b, and c, rank the electric potential, greatest first. (d) At points a, b, and c, rank the electric potential energy of the charge carriers, greatest first.

**Answers**

(a) rightward
(b) all tie
(c) b, then a and c tie
(d) b, then a and c tie
48 A standard flashlight battery can deliver about 2.0 W.h of energy before it runs down.
(a) If a battery costs US$0.80, what is the cost of operating a 100 W lamp for 8.0 h using batteries?
(b) What is the cost if energy is provided at the rate of US$0.06 per kilowatt-hour?

Answers
(a) $3.2 \times 10^2$ US
(b) $0.048$ US

49 A solar cell generates a potential difference of 0.10 V when a 500 Ω resistor is connected across it, and a potential difference of 0.15 V when a 1000 Ω resistor is substituted.
(a) What is the internal resistance of the solar cell?
(b) What is the emf of the solar cell?
(c) The area of the cell is 5.0 cm², and the rate per unit area at which it receives energy from light is 2.0 mW/cm². What is the efficiency of the cell for converting light energy to thermal energy in the 1000 Ω external resistor?

Answers
(a) 1.0 kΩ
(b) 0.30 V
(c) 0.23%

50 Answer the following questions.
(a) In electron-volts, how much work does an ideal battery with a 12.0 V emf do on an electron that passes through the battery from the positive to the negative terminal?
(b) If $3.40 \times 10^{-7}$ electrons pass through each second, what is the power of the battery in watts?

Answers
(a) 12.0 eV
(b) 6.53 W

51 Answer the following questions.
(a) What advantage does 120 V operation offer over 240 V?
(b) What disadvantage does 120 V operation offer over 240 V?

Answers
(a) all tie
(b) $R_1, R_2, R_3$
A battery has an emf of 12 V and internal resistance of 2 Ω. If the current in the battery is equal to 12 V, what is the current? (a) Is the terminal-to-terminal potential difference greater than, less than, or from the negative to the positive terminal? (b) Is the terminal-to-terminal potential difference greater than, less than, or from the positive to the negative terminal? (c) Is the terminal-to-terminal potential difference greater than, less than, or zero?

**Answers**

(a) less
(b) greater
(c) equal

In the figure, the ideal batteries have emfs \( E_1 = 12 \) V and \( E_2 = 6.0 \) V and the resistors have resistances \( R_1 = 4.0 \) Ω and \( R_2 = 8.0 \) Ω. (a) What is the current in resistor 1? (b) What is the dissipation rate in resistor 1? (c) What is the dissipation rate in resistor 2? (d) What is the energy transfer rate in battery 1? (e) What is the energy transfer rate in battery 2? (f) Is energy being supplied or absorbed by battery 1? (g) Is energy being supplied or absorbed by battery 2?

**Answers**

(a) 0.50 A
(b) 1.0 W
(c) 2.0 W
(d) 6.0 W
(e) 3.0 W
(f) supplied
(g) absorbed

In the figure, the ideal batteries have emfs \( E_1 = 150 \) V and \( E_2 = 50 \) V and the resistances are \( R_1 = 3.0 \) Ω and \( R_2 = 2.0 \) Ω. If the potential at P is defined to be 100 V, what is the potential at Q?

**Answers**

-10 V

In the figure, take \( E_1 = 2.0 \) V, \( E_2 = 3.0 \) V, and \( r_1 = r_2 = 3.0 \) Ω. (a) What value must R have if the current in the circuit is to be 1.0 mA? (b) What is the rate at which thermal energy appears in R?

**Answers**

(a) 9.9 \times 10^{-7} \Omega
(b) 9.9 \times 10^{-7} \text{ W}
In figure a, both batteries have emf $\mathcal{E} = 1.20$ V and the external resistance R is a variable resistor. Figure b gives the electric potentials V between the terminals of each battery as functions of R: Curve 1 corresponds to battery and curve 2 corresponds to battery 2.
(a) What is the internal resistance of battery 1?
(b) What is the internal resistance of battery 2?

Answers
(a) 0.20 $\Omega$
(b) 0.30 $\Omega$

In the figure, battery 1 has emf $\mathcal{E}_1 = 12.0$ V and internal resistance $r_1 = 0.016$ $\Omega$ and battery 2 has emf $\mathcal{E}_2 = 12.0$ 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?

Answers
(a) 0.004 $\Omega$
(b) 1

A power supply has a fixed output voltage of 12.0 V, but you need $V_1 = 3.0$ V for an experiment.
(a) Using the voltage divider shown in the figure, what should $R_1$ be if $R_2$ is 10.0 $\Omega$?
(b) What will the terminal voltage $V_T$ be if you connect a load to the 3.0-V terminal, assuming the load has a resistance of 7.0 $\Omega$?

In the figure, $R_1 = R_2 = 4.00$ $\Omega$ and $R_3 = 2.50$ $\Omega$. Find the equivalent resistance between points D and E. (Hint: Imagine that a battery is connected across those points.)

Answers
4.50 $\Omega$
The figure shows five 5.00 \( \Omega \) resistors.
(a) Find three equivalent resistance between points F and H.
(b) Find three equivalent resistance between points F and G.
(Hint: For each pair of points, imagine that a battery is connected across the pair.)

\[
\text{Answers}
\]

(a) 2.50 \( \Omega \)
(b) 3.13 \( \Omega \)

In the figure, the current in resistance 6 is \( i_6 = 1.40 \text{ A} \) and the resistances are \( R_1 = R_2 = R_3 = 2.00 \text{ } \Omega \), \( R_4 = 16.0 \text{ } \Omega \), \( R_5 = 8.00 \text{ } \Omega \), and \( R_6 = 4.00 \text{ } \Omega \). What is the emf of the ideal battery?

\[
\text{Answers}
\]

48.3 V

In the figure, \( R_4 = 100 \text{ } \Omega \), \( R_5 = R_6 = 50.0 \text{ } \Omega \), and the ideal battery has emf \( \mathcal{E} = 6.00 \text{ V} \).
(a) What is the equivalent resistance?
(b) What is \( i \) in resistance 1?
(c) What is \( i \) in resistance 2?
(d) What is \( i \) in resistance 3?
(e) What is \( i \) in resistance 4?

\[
\text{Answers}
\]

(a) 119 \( \Omega \)
(b) 150.5 mA
(c) 119.0 mA
(d) 19.0 mA
(e) 12.5 mA

Figure a, resistor 3 is a variable resistor and the ideal battery has emf \( \mathcal{E} = 12 \text{ V} \). Figure b gives the current \( i \) through the battery as a function of \( R_3 \). The curve has an asymptote of 2.0 mA as \( R_3 \rightarrow \infty \).
(a) What is the resistance \( R_3 \)?
(b) What is the resistance \( R_2 \)?

\[
\text{Answers}
\]

(a) 2.0 k\( \Omega \)
(b) 4.0 k\( \Omega \)
The ideal battery in figure a has emf \( \mathcal{E} = 6.0 \) V. Plot in figure b gives the current \( i \) that can appear in resistor 1 of the circuit versus the electric potential difference \( V \) set up across that resistor. Plots 2 and 3 are similar plots for resistors 2 and 3, respectively. What is the current in resistor 1.

![Image](image1.png)

**Answers**

0.82 mA

---

An automobile gasoline gauge is shown schematically in the figure. The indicator (on the dashboard) has a resistance of 10 \( \Omega \). The tank unit is a float connected to a variable resistor whose resistance varies linearly with the volume of gasoline. The resistance is 140 \( \Omega \) when the tank is empty and 20 \( \Omega \) when the tank is full.

(a) Find the current in the circuit when tank is empty.
(b) Find the current in the circuit when tank is half-full.
(c) Find the current in the circuit when tank is full. Treat the battery as ideal.

![Image](image2.png)

**Answers**

(a) 80 mA
(b) 0.13 A
(c) 0.40 A

---

The figure shows a circuit of four resistors that are connected to a larger circuit. The graph below the circuit shows the electric potential \( V(x) \) as a function of position \( x \) along the lower branch of the circuit, through resistor 4. The graph above the circuit shows the electric potential \( V(x) \) versus position \( x \) along the upper branch of the circuit, through resistors 1, 2, and 3. Resistor 3 has a resistance of 200 \( \Omega \).

(a) What is the resistance of resistor 1?
(b) What is the resistance of resistor 2?

![Image](image3.png)

**Answers**

(a) 80 \( \Omega \)
(b) 200 \( \Omega \)

---

In the figure \( R_1 = R_2 = 10.0 \) \( \Omega \), and the ideal battery has emf \( \mathcal{E}_2 = 12.0 \) V.

(a) What value of \( R_3 \) maximizes the rate at which the battery supplies energy?
(b) What is that maximum rate at which the battery supplies energy?

![Image](image4.png)

**Answers**

(a) 0
(b) 4.4 W
In the figure $\mathcal{E} = 12.0 \, \text{V}$, $R_1 = 2000 \, \Omega$, $R_2 = 3000 \, \Omega$, and $R_3 = 4000 \, \Omega$.
(a) What is the potential difference $V_A - V_B$?
(b) What is the potential difference $V_B - V_C$?
(c) What is the potential difference $V_C - V_D$?
(d) What is the potential difference $V_A - V_C$?

**Answers**

(a) 5.25 V
(b) 1.50 V
(c) 5.25 V
(d) 6.75 V

The figure shows a battery connected across a uniform resistor $R_0$. A sliding contact can move across the resistor from $x = 0$ at the left to $x = 10 \, \text{cm}$ at the right. Moving the contact changes how much resistance is to the left of the contact and how much is to the right. Find the rate at which energy is dissipated in resistor $R$ as a function of $x$. Plot the function for $\mathcal{E} = 50 \, \text{V}$, $R = 2000 \, \Omega$, and $R_0 = 100 \, \Omega$.

**Answers**

$100\mathcal{E}^2 x^2 R_0^{-2} (100RR_0^{-1} + 10x - x^2)^2$, $x$ in cm

In the figure, put $\mathcal{E} = 2.0 \, \text{V}$ and $r = 100 \, \Omega$.
(a) Plot the current across $R$, as functions of $R$ over the range 0 to 500. Plot.
(b) Plot the potential difference across $R$, as functions of $R$ over the range 0 to 500. Make both plots on the same graph.
(c) Make a third plot by multiplying together, for various values of $R$, the corresponding values on the two plotted curves. What is the physical significance of this third plot?

**Answers**

(a)
(b)
(c) It gives the rate with which $R$ dissipates energy

For each circuit in the figure, are the resistors connected in series, in parallel, or neither?

**Answers**

(a) series
(b) parallel
(c) parallel
Answer the following questions.
(a) In figure a, are resistors $R_1$ and $R_2$ in series?
(b) In figure a, are $R_1$ and $R_2$ in parallel?
(c) Rank the equivalent resistances of the four circuits shown in the figure, greatest first.

![Circuit Diagrams]

Answers
(a) no
(b) yes
(c) all tie

You are to connect resistors $R_1$ and $R_2$, with $R_1 > R_2$, to a battery, first individually, then in series, and then in parallel. Rank those arrangements according to the amount of current through the battery, greatest first.

Answers
parallel, $R_2$, $R_1$, series

A 650 $\Omega$ and a 2200 $\Omega$ resistor are connected in series with a 12 V battery. What is the voltage across the 2200 $\Omega$ resistor?

Answer
$9.3 \Omega$

Eight identical lights are connected in series across a 110-V line.
(a) What is the voltage across each bulb?
(b) If the current is 0.50 A, what is the resistance of each bulb, and what is the power dissipated in each?

Answer
(a) 14 V
(b) 28 $\Omega$, 6.9 W

A flashlight bulb rated at 2.5 W and 3.0 V is operated by a 9.0-V battery. To light the bulb at its rated voltage and power, a resistor $R$ is connected in series as shown in the figure. What value should the resistor have?

![Flashlight Circuit Diagram]

Answer
7.2 $\Omega$
A light bulb marked “75 W [at] 120 V” is screwed into a socket at one end of a long extension cord, in which each of the two conductors has resistance 0.800 $\Omega$. The other end of the extension cord is plugged into a 120 V outlet. Draw a circuit diagram and find the actual power delivered to the bulb in this circuit.

**Answers**

73.8 W

Four copper wires of equal length are connected in series. Their cross sectional areas are 1.00 cm$^2$, 2.00 cm$^2$, 3.00 cm$^2$, and 5.00 cm$^2$. A potential difference of 120 V is applied across the combination. Determine the voltage across the 2.00 cm$^2$ wire.

**Answers**

29.5 V

In the figure let $R_1 = 11.0 \Omega$, $R_2 = 22.0 \Omega$, and let the battery have a terminal voltage of 33.0 V.

(a) In the series circuit, which resistor uses more power?
(b) Verify that the sum of the power ($I^2R$) used by each resistor equals the power supplied by the battery ($P = I \Delta V$). (c) Which circuit configuration uses more power?

**Answers**

(a) The 11.0 $\Omega$ resistor uses more power
(b) 148 W
148 W
(c) The 22.0 $\Omega$ resistor uses more power
(d) 33.0 W
33.0 W
(e) The parallel configuration uses more power.

Four 18.0 $\Omega$ resistors are connected in parallel across a 25.0 V ideal battery. What is the current through the battery?

**Answers**

5.56 A

A battery with an emf of 12.0 V shows a terminal voltage of 11.8 V when operating in a circuit with two light bulbs rated at 3.0 W (at 12.0 V) which are connected in parallel. What is the battery’s internal resistance?

**Answer**

0.4 $\Omega$

A 75-W, 110-V bulb is connected in parallel with a 40-W, 110-V bulb. What is the net resistance?

**Answer**

110 $\Omega$

When resistors are connected in parallel, which of the following would be the same for each resistor: potential difference, current, power?

**Answers**

The resistances in figures a and b are all 6.0 $\Omega$, and the batteries are ideal 12 V batteries.

(a) When switch S in figure a is closed, what is the change in the electric potential $V_1$, across resistor 1, or does $V_1$ remain the same?
(b) When switch S in figure b is closed, what is the change in $V_1$, across resistor 1, or does $V_1$ remain the same?

**Answers**

(a) same
(b) -2.0 V
Initially, a single resistor $R_1$ is wired to a battery. Then resistor $R_2$ is added in parallel.

(a) Is the potential difference across $R_1$ now more than, less than, or the same as previously?
(b) Is the current $i$, through $R_1$, now more than, less than, or the same as previously?
(c) Is the equivalent resistance $R_{12}$ of $R_1$ and $R_2$ more than, less than, or equal $R_1$?
(d) Is the total current through $R_1$ and $R_2$ together more than, less than, or equal to the current through $R_1$ previously?

Answers

(a) same
(b) same
(c) less
(d) more

Four 240 Ohm light bulbs are connected in series.

(a) What is the total resistance of the circuit?
(b) What is their resistance if they are connected in parallel?

Answer

(a) 960 Ohm
(b) 60 Ohm

Answer the following questions:
(a) Determine the equivalent resistance of the circuit shown in the figure.
(b) Determine the voltage across each resistor.

Answer

(a) 840 Ohm
(b) 6.7 V, 5.3 V

In the circuit shown in the figure, the 33 Ohm resistor dissipates 0.50 W. What is the battery voltage?

Answer

8.472 V

A series circuit consists of three identical lamps connected to a battery as shown in the figure. The switch $S$ is closed
(a) What happens to the intensities of lamps A and B?
(b) What happens to the intensity of lamp C?
(c) What happens to the current in the circuit?
(d) What happens to the voltage across the three lamps?
(e) Does the power delivered to the circuit increase, decrease, or remain the same?
Answer the following questions:
(a) When applying Kirchhoff’s loop rule (such as in the figure), does the sign (or direction) of a battery’s emf depend on the direction of current through the battery?
(b) What about the terminal voltage?

Answer

Calculate the current in the circuit of the figure and show that the sum of all the voltage changes around the circuit is zero.

Answer

Determine the terminal voltage of each battery in the figure.

Answer

Answer the following questions:
(a) What is the potential difference between points a and d in the figure.
(b) What is the terminal voltage of each battery?

Answer

For the circuit shown in the figure, find the potential difference between points a and b. Each resistor has $R = 75 \, \Omega$ and each battery is 1.5 V.

Answer

0 V
Determine the magnitudes and directions of the currents in each resistor shown in the figure. The batteries have emfs of \( E_1 \) = 9.0 V and \( E_2 \) = 12.0 V and the resistors have values of \( R_1 \) = 25 \( \Omega \), \( R_2 \) = 18 \( \Omega \), and \( R_3 \) = 35 \( \Omega \).

![Image of the circuit](image)

**Answer**

- \( I_1 \) = 0.1811 A, up
- \( I_2 \) = 0.3145 A, left
- \( I_3 \) = 0.1334 A, right

100 Calculate the currents in each resistor of the figure.

![Image of the circuit](image)

**Answer**

- \( 2\Omega \) = 0.26 A
- \( 6\Omega \) = 0.028 A
- \( 8\Omega \) = 0.29 A
- \( 10\Omega \) = 0.26 A
- \( 12\Omega \) = 0.29 A

A Wheatstone bridge is a type of “bridge circuit” used to make measurements of resistance. The unknown resistance to be measured, \( R_x \), is placed in the circuit with accurately known resistances \( R_1 \), \( R_2 \), and \( R_3 \) (see the figure). One of these, \( R_x \), is a variable resistor which is adjusted so that when the switch is closed momentarily, the ammeter shows zero current flow. 

(a) Determine \( R_x \) in terms of \( R_1 \), \( R_2 \), and \( R_3 \).

(b) If a Wheatstone bridge is “balanced” when \( R_1 = 630 \Omega \), \( R_2 = 972 \Omega \), and \( R_3 = 42.6 \Omega \), what is the value of the unknown resistance?

![Image of the Wheatstone bridge](image)

**Answer**

(a) \( R_x(R_1/R_3) \)

(b) 65.7 \( \Omega \)

The current through the 4.0-k\( \Omega \) resistor in the figure is 3.50 mA. What is the terminal voltage \( V_{ab} \) of the “unknown” battery? (There are two answers. Why?) [**Hint:** use conservation of energy or Kirchhoff’s rules.]

![Image of the circuit](image)

**Answer**

52.3 V

-28.3 V
Answer the following questions:
(a) For the circuit shown in the figure, determine the current through the 14-V battery.
(b) For the circuit shown in the figure, determine the potential difference between points a and b, $V_a - V_b$.

![Circuit Diagram]

**Answer**

(a) $6.7 \times 10^{-7}$ A, upward
(b) -16 V

104 In the circuit of the figure, determine the current in each resistor and the voltage across the 200 Ω resistor.

![Circuit Diagram]

**Answers**

$\bar{w} = 1.00$ A upward in 200 Ω
$z = 4.00$ A upward in the 70.0 Ω
$x = 3.00$ A upward in 80.0 Ω
$y = -8.00$ a downward in 20.0 Ω
$200 \Omega = 200$ V

105 Use the circuit shown in the figure to solve the following problems.
(a) Calculate the current in the 2.00 Ω resistor.
(b) Calculate the potential difference between points a and b.

![Circuit Diagram]

**Answers**

(a) $I_s = 909$ mA
(b) -1.82 V

106 What is the main difference between an analog voltmeter and an analog ammeter?

**Answer**

107 What would happen if you mistakenly used an ammeter where you needed to use a voltmeter?

**Answer**

108 When the resistor R in the figure is 35 Ω, the high-resistance voltmeter reads 9.7 V. When R is replaced by a 9.0 Ω resistor, the voltmeter reading drops to 8.1 V. What are the emf and internal resistance of the battery?

![Circuit Diagram]

**Answer**

2.569 Ω
10.41 V
(a) A voltmeter and an ammeter can be connected as shown in figure a to measure a resistance R. If V is the voltmeter reading, and I is the ammeter reading, the value of R will not quite be V/I (as in Ohm’s law) because some of the current actually goes through the voltmeter. Show that the actual value of R is given by $1/R = 1/V - 1/R_v$, where $R_v$ is the voltmeter resistance. Note that $R \approx V/I$ if $R_v >> R$.

(b) A voltmeter and an ammeter can also be connected as shown in figure b to measure a resistance R. Show in this case that $R = V/I - R_A$, where V and I are the voltmeter and ammeter readings and $R_A$ is the resistance of the ammeter. Note that $R \approx V/I$ if $R_A << R$.

\[ \text{(a)} \quad 2.33 \times 10^{-9} \text{ F} \]
\[ \text{(b)} \quad 1.42 \times 10^{-5} \text{ s} \]

In the figure the total resistance is 15.0 kΩ, and the battery’s emf is 24.0 V. The time constant is measured to be 35.0 µs.
(a) Calculate the total capacitance of the circuit
(b) Calculate the time it takes for the voltage across the resistor to reach 16.0 V after the switch is closed.

\[ \text{Answer} \]

Electrocardiographs are often connected as shown in the figure. The leads are said to be capacitively coupled. A time constant of 3.0 s is typical and allows rapid changes in potential to be recorded accurately. If $C = 3.0 \mu$F, what value must $R$ have? [Hint: consider each leg as a separate circuit.]

\[ \text{Answer} \]

$9.3 \times 10^2 \text{ s}$
Two resistors and two uncharged capacitors are arranged as shown in the figure. Then a potential difference of 24 V is applied across the combination as shown.

(a) What is the potential at point a with switch S open? (Let \( V = 0 \) at the negative terminal of the source.)
(b) What is the potential at point b with the switch open?
(c) When the switch is closed, what is the final potential of point b?
(d) How much charge flows through the switch S after it is closed?

![Circuit Diagram]

**Answer**

(a) 8.0 V
(b) 16 V
(c) 8.0 V
(d) 5.76 \( \mu \)C

---

A heart pacemaker is designed to operate at 72 beats/min using a 7.5 \( \mu \)F capacitor in a simple \( RC \) circuit. What value of resistance should be used if the pacemaker is to fire (capacitor discharge) when the voltage reaches 63% of maximum?

**Answer**

1.1 \( \times 10^{-5} \) \( \Omega \)

---

The circuit shown in the figure uses a neon-filled tube. This neon lamp has a threshold voltage \( V_0 \) for conduction, because no current flows until the neon gas in the tube is ionized by a sufficiently strong electric field. Once the threshold voltage is exceeded, the lamp has negligible resistance. The capacitor stores electrical energy, which can be released to flash the lamp. Assume that \( C = 0.150 \ \mu F, R = 2.35 \times 10^6 \ \Omega, V_0 = 90.0 \) V and \( E = 105 \) V.

(a) Assuming that the circuit is hooked up to the emf at time \( t = 0 \), at what time will the light first flash?
(b) If the value of \( R \) is increased, will the time you found in part (a) increase or decrease?
(c) The flashing of the lamp is very brief. Why?
(d) Explain what happens after the lamp flashes for the first time.

![Circuit Diagram with Neon Lamp]

**Answer**

(a) 0.686 s
(b) time will increase
(c) the capacitor discharges through a very low resistance (lamp) and so the discharge time constant is very short
(d) The current through the 20 \( \Omega \) resistor in the figure does not change whether the two switches \( S_1 \) and \( S_2 \) are both open or both closed. Use this clue to determine the value of the unknown resistance \( R \).

![Circuit Diagram with Two Switches]

**Answer**

100 \( \Omega \)
Referring to the figure, describe what happens to the light bulb after the switch is closed. Assume that the capacitor has a large capacitance and is initially uncharged, and assume that the light illuminates when connected directly across the battery terminals.

Answers

A 2.00 nF capacitor with an initial charge of 5.10 μC is discharged through a 1.30 kΩ resistor.
(a) Calculate the current in the resistor 9.00 μs after the resistor is connected across the terminals of the capacitor.
(b) What charge remains on the capacitor after 8.00 μs?
(c) What is the maximum current in the resistor?

Answers

(a) -61.6 mA
(b) 0.235 μC
(c) 1.96 A

A capacitor in an RC circuit is charged to 60.0% of its maximum value in 0.900 s. What is the time constant of the circuit?

Answers

0.982 s

In the circuit of the figure, the switch S has been open for a long time. It is then suddenly closed.
(a) Determine the time constant before the switch is closed.
(b) Determine the time constant after the switch is closed.
(c) Let the switch be closed at t = 0. Determine the current in the switch as a function of time

Answers

(a) 1.50 s
(b) 1.00 s
(c) 200 μA + (100μA)e^{-1.00t}

The circuit in the figure has been connected for a long time.
(a) What is the voltage across the capacitor?
(b) If the battery is disconnected, how long does it take the capacitor to discharge to one tenth of its initial voltage?

Answers

(a) 6.00 V
(b) 8.29 μs

A 4.00 MΩ resistor and a 3.00 μF capacitor are connected in series with a 12.0 V power supply.
(a) What is the time constant for the circuit?
(b) Express the current in the circuit and the charge on the capacitor as functions of time.

Answers

(a) 12.0 s
(b) $q = 36.0 \, \mu C[1 - e^{-12.0}]$
$I = 3.00 \, \mu A e^{-12.0}$
The values of the components in a simple series RC circuit containing a switch shown in the figure are \( C = 1.00 \, \mu F \), \( R = 2.00 \times 10^3 \, \Omega \), and \( E = 10.0 \, V \). Answer the following questions at the instant 10.0 seconds after the switch is closed.

(a) Calculate the charge on the capacitor
(b) Calculate the current in the resistor.
(c) Calculate the rate at which energy is being stored in the capacitor.
(d) Calculate the rate at which energy is being delivered by the battery.

\[ 5.87 \times 10^3 \, \Omega \]

The table gives four sets of values for \( V \) the circuit elements in the figure above the table.

(a) Rank the sets according to the initial current (as the switch is closed on a), greatest first.
(b) Rank the sets according to the time required for the current to decrease to half its initial value, greatest first.

<table>
<thead>
<tr>
<th>( V ) (V)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R ) (\Omega)</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>( C ) (\mu F)</td>
<td>3</td>
<td>2</td>
<td>0.5</td>
<td>2</td>
</tr>
</tbody>
</table>

\[ 4.61 \]

A capacitor with initial charge \( q_i \) is discharged through a resistor.

(a) What multiple of the time constant \( \tau \) gives the time the capacitor takes to lose the first one-third of its charge?
(b) What multiple of the time constant \( \tau \) gives the time the capacitor takes to lose two-thirds of its charge?

\[ 0.41 \]
\[ 1.1 \]

What multiple of the time constant \( \tau \) gives the time taken by an initially uncharged capacitor in an RC series circuit to be charged to 99.0\% of its final charge?

\[ 4.61 \]
130 In an RC series circuit $E = 12.0 \, \text{V}$, $R = 1.40 \, \text{M} \Omega$ and $C = 1.80 \, \mu\text{F}$.
(a) Calculate the time constant.
(b) Find the maximum charge that will appear on the capacitor during charging.
(c) How long does it take for the charge to build up to 16.0 \mu\text{C}?

Answers
(a) 2.52 s
(b) 21.6 \mu\text{C}
(c) 3.40 s

131 A 15.0 \text{k} \Omega \text{ resistor and a capacitor are connected in series, and then a 12.0 \text{V} potential difference is suddenly applied across them. The potential difference across the capacitor rises to 5.00 \text{V} in 1.30 \text{s.}}
(a) Calculate the time constant of the circuit.
(b) Find the capacitance of the capacitor.

Answers
(a) 2.41 \mu\text{s}
(b) 161 \text{pF}

132 Switch S in the figure is closed at time $t = 0$, to begin charging an initially uncharged capacitor of capacitance $C = 15.0 \, \text{\mu F}$ through a resistor of resistance $R = 20.0 \, \Omega$. At what time is the potential across the capacitor equal to that across the resistor?

Answers
0.208 ms

133 A capacitor with an initial potential difference of 100 V is discharged through a resistor when a switch between them is closed at $t = 0$. At $t = 10.0 \, \text{s}$, the potential difference across the capacitor is 1.00 V.
(a) What is the time constant of the circuit?
(b) What is the potential difference across the capacitor at $t = 17.0 \, \text{s}$?

Answers
(a) 2.17 s
(b) 39.6 mV

134 The potential difference between the plates of a leaky (meaning that charge leaks from one plate to the other) 2.0 \text{ \mu F} capacitor drops to one-fourth its initial value in 2.0 s. What is the equivalent resistance between the capacitor plates?

Answers
0.72 \text{ M} \Omega
In the circuit of the figure, $E = 12 \text{kV}$, $C = 6.5 \text{?F}$, $R_1 = R_2 = R_3 = 0.73 \text{M?}$. With C completely uncharged, switch S is suddenly closed (at $t = 0$).

(a) At $t = 0$, what is current $i_1$ in resistor 1?
(b) At $t = 0$, what is current $i_2$ in resistor 2?
(c) At $t = 0$, what is current $i_3$ in resistor 3?
(d) At $t = \infty$ (that is, after many time constants), what is $i_1$?
(e) At $t = \infty$ (that is, after many time constants), what is $i_2$?
(f) At $t = \infty$ (that is, after many time constants), what is $i_3$?

(g) What is the potential difference $V_2$ across resistor 2 at $t = 0$?
(h) What is the potential difference $V_2$ across resistor 2 at $t = \infty$?

(i) Sketch $V_2$ versus $t$ between these two extreme times.

**Answers**

(a) 1.1 mA
(b) 0.55 mA
(c) 0.55 mA
(d) 0.82 mA
(e) 0.82 mA
(f) 0
(g) $4.0 \times 10^3 \text{ V}$
(h) $6.0 \times 10^3 \text{ V}$

A controller on an electronic arcade game consists of a variable resistor connected across the plates of a $0.220 \text{?F}$ capacitor. The capacitor is charged to 5.00 V, then discharged through the resistor. The time for the potential difference across the plates to decrease to 0.800 V is measured by a clock inside the game. The range of discharge times that can be handled effectively is from 10.0 ?s to 6.00 ms.

(a) What should be the lower value of the resistance range of the resistor?
(b) What should be the higher value of the resistance range of the resistor?

**Answers**

(a) $24.8 \Omega$
(b) $14.9\text{k}\Omega$