CURRENT AND RESISTANCE

1. A car battery is rated at 80 A · h. An ampere-hour is a unit of:
   A. power
   B. energy
   C. current
   D. charge
   E. force

2. Current has units:
   A. kilowatt·hour
   B. coulomb/second
   C. coulomb
   D. volt
   E. ohm

3. Current has units:
   A. kilowatt·hour
   B. amp ere
   C. coulomb
   D. volt
   E. ohm

4. The units of resistivity are:
   A. ohm
   B. ohm·meter
   C. ohm/meter
   D. ohm/meter^2
   E. None of these

5. Therate at which electrical energy is used may be measured in:
   A. watt/second
   B. watt·second
   C. watt
   D. joule·second
   E. kilowatt·hour

6. Energy may be measured in:
   A. kilowatt
   B. joule·second
   C. watt
   D. watt·second
   E. volt/ohm

7. Which one of the following quantities is correctly matched to its unit?
   A. Power □ kW·h
   B. Energy □kW
   C. Potential difference □ J/C
   D. Current □A/s
   E. Resistance □ V/C

8. Current is a measure of:
   A. Force that moves a charge past a point
   B. resistance to the movement of a charge past a point
   C. energy used to move a charge past a point
   D. amount of charge that moves past a point per unit time
   E. speed with which a charge moves past a point

9. A 60-watt light bulb carries a current of 0.5A. The total charge passing through it in one hour is:
   A. 120 C B. 3600 C C. 3000 C D. 2400 C E. 1800 C

10. A 10-ohm resistor has a constant current. If 1200 C of charge flow through it in 4 minutes what is the value of the current?
    A. 3.0 A B. 5.0 A C. 11 A D. 15 A E. 20 A

11. If the potential difference across a resistor is doubled:
    A. only the current is doubled
    B. only thecurrent is halved
    C. only the resistance is doubled
    D. only ther esistance is halved
    E. Both thecurrent and resistance are doubled

12. A cylindrical copper rod has resistance R. It is reformed to twice its original length with no change of volume. Its new resistance is:
    A. R B. 2R C. 4R D. 8R E. R/2

13. Five cylindrical wires are made of the same material. Their lengths and radii are

wire 1: length L, radius r
wire 2: length L/4, radius r/2
wire 3: length L/2, radius r/2
wire 4: length L, radius r/2
wire 5: length 5L, radius 2r

Rank the wires according to their resistances, least to greatest.

A. 1,2,3, 4,5
B. 5,4,3, 2,1
C. 1 and 2 tie, then 5, 3,4
D. 1,3,4,2,5
E. 1,2,4,3,5

14. Of the following, the copper conductor that has the least resistance is:

A. thin,long and hot
B. thick, short and cool
C. thick, long and hot
D. thin, short and cool
E. thin, short and hot

15. The resistance of a rod does NOT depend on:

A. its temperature
B. its material
C. its length
D. its conductivity
E. the shape of its (fixed) cross-sectional area

16. A certain wire has resistance R. Another wire, of the same material, has half the length and half the diameter of the first wire. The resistance of the second wire is:

A. R/4 B. R/2 C. R D. 2R E. 4R

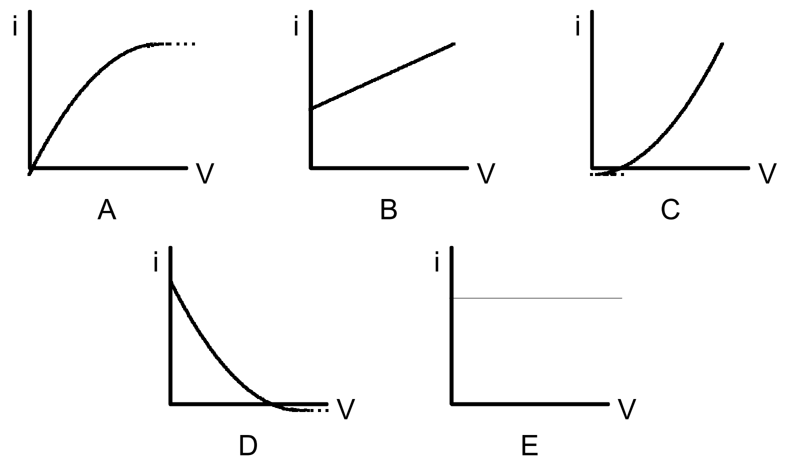
17. A certain sample carries a current of 4A when the potential difference is 2V and a current of 10 A when the potential difference is 4 V. This sample:

A. obeys Ohm's law
B. has a resistance of 0.5 Ω at 1V
C. has a resistance of 2.5 Ω at 1V
D. has a resistance of 2.5 Ω at 2V
E. does not have a resistance

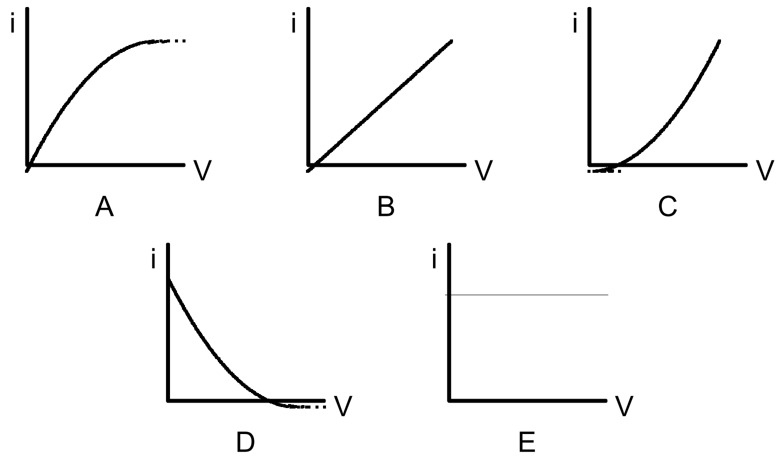
18. A current of 0.5A exists in a 60-ohm lamp. The applied potential difference is:

A. 15V B. 30V C. 60V D. 120V E. None of these

19. Which of the following graphs best represents the current-voltage relationship of an incandescent light bulb?



20. Which of the following graphs best represents the current-voltage relationship for a device that obeys Ohm's law?



21. You wish to triple the rate of energy dissipation in a heating device. To do thisyou could triple
   A. the potential difference keeping the resistance the same
   B. the current keeping the resistance the same
   C. the resistance keeping the potential difference the same
   D. the resistance keeping the current the same
   E. both the potential difference and current

22. A student kept her 60-watt, 120-volt study lamp turned on from 2:00 PM until 2:00 AM. How many coulombs of charge went through it?
   A. 150
   B. 3, 600
   C. 7, 200
   D. 18, 000
   E. 21, 600

23. A flat iron is marked 120V, 600 W. In normal use, the current in it is:

   A. 2A B. 4A C. 5A D. 7.2A E. 0.2A

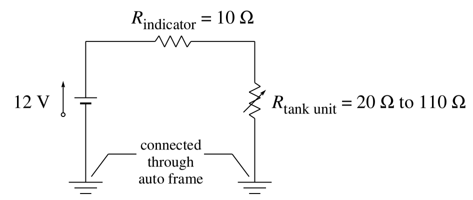
24. It is better to send 10,000 kW of electric power long distances at 10,000V rather than at 220V because:
   A. there is less heating in the transmission wires
   B. the resistance of the wires is less at high voltages
   C. more current is transmitted at high voltages
   D. the insulation is more effective at high voltages
   E. the iR drop along the wires is greater at high voltage

25. You buy a 75W light bulb. The label means that:
   A. no matter how you use the bulb, the power will be 75W
   B. the bulb was filled with 75W at the factory
   C. the actual power dissipated will be much higher than 75 W since most of the power appears as heat
   D. the bulb is expected to burn out after you use up its 75W
   E. none of the above

26. A current of 0.3 A is passed through a lamp for 2 minutes using a 6-V power supply. The energy dissipated by this lamp during the 2 minutes is:

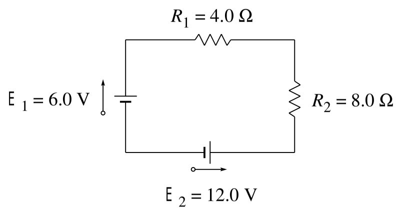
   A. 1.8J B. 12J C. 20J D. 36J E. 216J

25. *Automobile gas gauge* (HRW chapter 27)
A gasoline gauge for an automobile is shown schematically below.



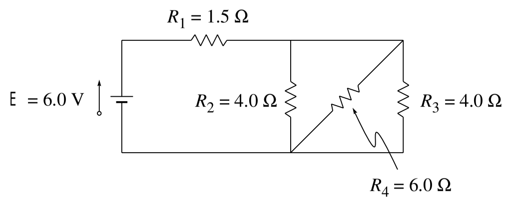
A wire runs from the positive end of the battery (under the hood) to the indicator gauge (on the dashboard, with resistance 10 Ω), and another wire runs from the indicator gauge to the tank unit (at the rear of the car). There is no return wire: instead, the negative end of the battery and the bottom end of the tank unit are each connected to the steel automobile frame, and the return current runs through the frame itself. (These two connections are said to be "grounded to the frame".) The tank unit is a float connected to a variable resistor whose resistance is 20 Ω when the tank is full, 110 Ω when the tank is empty, and varies linearly with the volume of gasoline. Find the current in the circuit when the tank is (a) full, (b) half-full, and (c) empty.

26. *A circuit with two batteries* (HRW chapter 27)
The batteries in this circuit have negligible internal resistance.

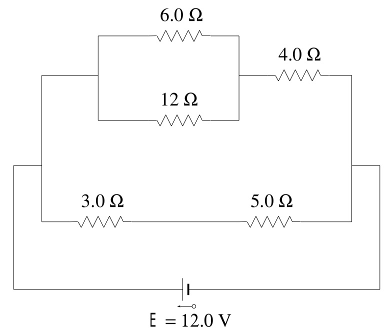


Find (a) the current in the circuit (including direction), (b) the power dissipated in each resistor, and (c) the energy transfer rate (including sign) at each battery.

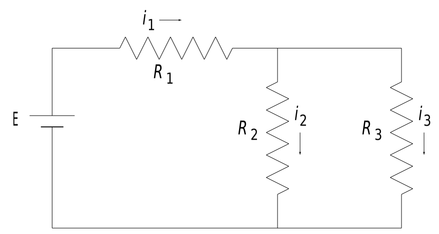
27. *A circuit with four resistors* (HRW chapter 27)
Find the equivalent resistance of this network and the current through each resistor. (The battery has negligible internal resistance.)



28. *A circuit with five resistors* (HRW section 27–7)
What is the potential difference across the 5.0 Ω resistor in the circuit below? *Hint:* Ignore irrelevant data.



29. *A simple circuit: derivation and exploration* (HRW section 27–7)
Suppose three resistors and a battery are connected as sketched below:



Consider all the circuit elements to be ideal. You know techniques for finding i_1, i_2, and i_3 in terms of R_1, R_2, R_3, and $\mathcal{E}$, but please don't find these expressions yet. Instead, work through the following steps:

a. Four friends independently find expressions for i_3. When they get together to compare results, they find that each of the four has obtained a different expression! The four candidate answers are

$$i_3 = \mathcal{E}\frac{R_3}{R_1R_2 + R_1R_3 + R_2R_3}, \quad (1)$$
$$i_3 = \mathcal{E}\frac{R_2}{R_1R_2 + R_1R_3 + R_2R_3}, \quad (2)$$
$$i_3 = \mathcal{E}\frac{1}{R_1 + R_1R_3 + R_2R_3}, \quad (3)$$
$$i_3 = \mathcal{E}\frac{R_2}{R_1R_2 - R_1R_3}. \quad (4)$$

Show that one candidate answer is dimensionally incorrect, one gives infinite current for perfectly legitimate values of the resistances, two give incorrect results for the special case $R_2 = 0$, and one gives incorrect results for the special case $R_3 = 0$. Verify that the remaining candidate is correct.

b. In this circuit, if every subscript "2" is changed to a subscript "3" and vice versa, the resulting circuit is exactly the same as the original. Use this symmetry to write down an expression for i_2 directly from the expression for i_3 without any intermediate steps.

c. Now that you know both i_3 and i_2, find i_1 through a single addition.

d. The current leaving the top of the battery and passing through R_1 is i_1. What is the current entering the bottom of the battery?

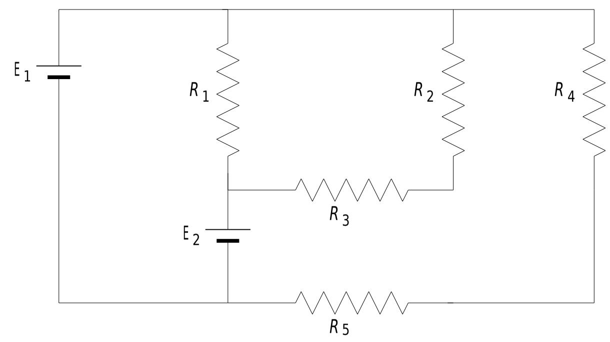
e. If the battery emf $\mathcal{E}$ is tripled, what happens to each of the currents?

f. If every resistance is doubled, what happens to each of the currents?

g. If R_3 is much greater than R_2, what is i_3? Is this what you expect?

h. Does current always take "the path of least resistance"?

30. *A circuit with five resistors and two batteries* (HRW section 27–7)



a. Below are three candidate expressions for the current through R_4 in the circuit sketched above. Without solving the problem, give at least one reason why each candidate *cannot* be correct.

$$\frac{\mathcal{E}_1}{R_4 + R_5 - R_1} \quad (1)$$
$$\frac{\mathcal{E}_2}{(R_2 + R_3)(R_4 + R_5)} \quad (2)$$
$$\frac{\mathcal{E}_1 R_3}{R_2(R_4 + R_5)} \quad (3)$$

b. Find a correct expression for the current through R_4.

[*Answers for part (a):* The first candidate gives infinite current when $R_1 = R_4 + R_5$. The second candidate does not have the dimensions of current. The third candidate lacks the required symmetry between R_2 and R_3. It also shows increased current with increased R_3—unexpected to say the least—and it predicts infinite current through R_4 if R_3 is infinite (e.g. if the wire between R_2 and R_3 is broken).]

31. *Resistors in parallel* (HRW section 27–7)

a. Show that the equivalent resistance of two resistors in parallel is

$$\frac{R_1 R_2}{R_1 + R_2}.$$

b. It is tempting to generalize this result and guess that the equivalent resistance of three resistors in parallel is

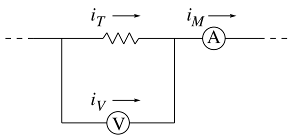
$$\frac{R_1 R_2 R_3}{R_1 + R_2 + R_3}.$$

Without doing a derivation, show that this guess is impossible.

c. Find the correct expression for the equivalent resistance of three resistors in parallel.

32. *Resistance measurement* (HRW chapter 27)

A voltmeter of resistance R_V and an ammeter of resistance R_A are connected as shown in an attempt to measure the resistance of a resistor.



If

$$\begin{aligned} \Delta V &= \text{voltage drop across resistor} \\ &= \text{voltage drop across voltmeter} \\ &= \text{voltmeter reading} \end{aligned}$$

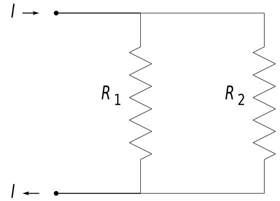
then the true resistance of the resistor is $R_T = \Delta V / i_T$. However the current i_T can't be measured directly — the ammeter measures a slightly different current i_M. Define the "measured resistance" $R_M = \Delta V / i_M$ and show that

$$\frac{1}{R_T} = \frac{1}{R_M} - \frac{1}{R_V}.$$

When R_V is much greater than R_M, how are R_M and R_T related?

33. *Principle of minimum power dissipation* (HRW chapter 27)

Part of a circuit consists of two resistors, R_1 and R_2, in parallel. Current I flows into the top of the pair and out of the bottom. It doesn't matter what is in the rest of the circuit, so I haven't shown it in the figure.



You know that the current I splits up so that i flows through R_1 and $(I - i)$ flows through R_2 (Kirchhoff's junction rule). And you know that you can calculate i by demanding that the voltage drop across R_1 is equal to the voltage drop across R_2 (Kirchhoff's loop rule). This problem demonstrates a different method, the principle of minimum power dissipation, that can also be used to calculate the amount of splitting.

a. Find the power dissipated in the two resistors $P(i)$ as a function of i, using only Kirchhoff's junction rule and not Kirchhoff's loop rule.

b. Find the value of i that minimizes $P(i)$.

c. Show that the value of i obtained in part (b) is the true current through R_1 as obtained through Kirchhoff's loop rule.

Although we have discussed only a single example, it turns out that the principle of minimum power dissipation always gives the correct currents in circuit problems. In most circumstances, it is easier to find currents using Kirchhoff's loop rule rather than the principle of minimum power dissipation, but the principle is nevertheless interesting. For example, it is a special case of the more general principle of minimum entropy production.

34. *Capacitor discharge* (HRW section 27–9)

You have two resistors of unknown but identical resistance. A 100 microfarad capacitor is charged by a 1.6 volt battery and then discharged through one of the resistors. The discharge is exponential with a half life (or "halving time") of 26.4 seconds.

Now the experiment is repeated, except that the capacitor is discharged through the two resistors connected in parallel. What will be the half life for this discharge? (As always, explain your reasoning in a sentence or two.)