Conceptual Questions

21.1 Resistors in Series and Parallel

1.

A switch has a variable resistance that is nearly zero when closed and extremely large when open, and it is placed in series with the device it controls. Explain the effect the switch in Figure 21.41 has on current when open and when closed.

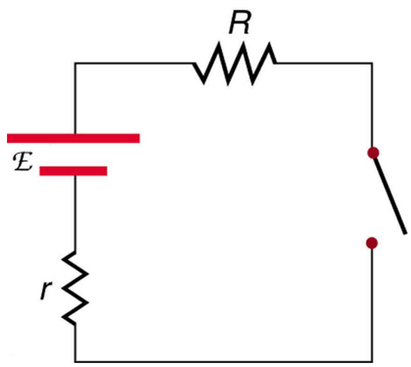

Figure 21.41 A switch is ordinarily in series with a resistance and voltage source. Ideally, the switch has nearly zero resistance when closed but has an extremely large resistance when open. (Note that in this diagram, the script E represents the voltage (or electromotive force) of the battery.)

2.

What is the voltage across the open switch in Figure 21.41?

3.

There is a voltage across an open switch, such as in Figure 21.41. Why, then, is the power dissipated by the open switch small?

4.

Why is the power dissipated by a closed switch, such as in Figure 21.41, small?

5.

A student in a physics lab mistakenly wired a light bulb, battery, and switch as shown in Figure 21.42. Explain why the bulb is on when the switch is open, and off when the switch is closed. (Do not try this—it is hard on the battery!)

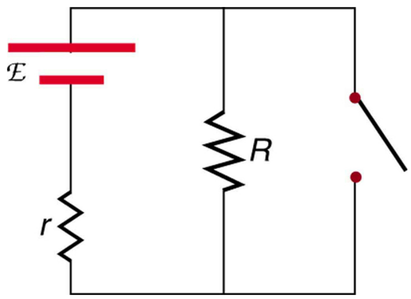

Figure 21.42 A wiring mistake put this switch in parallel with the device represented by R. (Note that in this diagram, the script E represents the voltage (or electromotive force) of the battery.)

6.

Knowing that the severity of a shock depends on the magnitude of the current through your body, would you prefer to be in series or parallel with a resistance, such as the heating element of a toaster, if shocked by it? Explain.

7.

Would your headlights dim when you start your car's engine if the wires in your automobile were superconductors? (Do not neglect the battery's internal resistance.) Explain.

8.

Some strings of holiday lights are wired in series to save wiring costs. An old version utilized bulbs that break the electrical connection, like an open switch, when they burn out. If one such bulb burns out, what happens to the others? If such a string operates on 120 V and has 40 identical bulbs, what is the normal operating voltage of each? Newer versions use bulbs that short circuit, like a closed switch, when they burn out. If one such bulb burns out, what happens to the others? If such a string operates on 120 V and has 39 remaining identical bulbs, what is then the operating voltage of each?

9.

If two household lightbulbs rated 60 W and 100 W are connected in series to household power, which will be brighter? Explain.

10.

Suppose you are doing a physics lab that asks you to put a resistor into a circuit, but all the resistors supplied have a larger resistance than the requested value. How would you connect the available resistances to attempt to get the smaller value asked for?

11.

Before World War II, some radios got power through a “resistance cord” that had a significant resistance. Such a resistance cord reduces the voltage to a desired level for the radio’s tubes and the like, and it saves the expense of a transformer. Explain why resistance cords become warm and waste energy when the radio is on.

12.

Some light bulbs have three power settings (not including zero), obtained from multiple filaments that are individually switched and wired in parallel. What is the minimum number of filaments needed for three power settings?

21.2 Electromotive Force: Terminal Voltage

13.

Is every emf a potential difference? Is every potential difference an emf? Explain.

14.

Explain which battery is doing the charging and which is being charged in Figure 21.43.

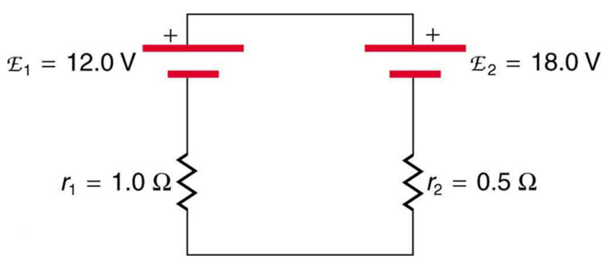

Figure 21.43

15.

Given a battery, an assortment of resistors, and a variety of voltage and current measuring devices, describe how you would determine the internal resistance of the battery.

16.

Two different 12-V automobile batteries on a store shelf are rated at 600 and 850 “cold cranking amps.” Which has the smallest internal resistance?

17.

What are the advantages and disadvantages of connecting batteries in series? In parallel?

18.

Semitractor trucks use four large 12-V batteries. The starter system requires 24 V, while normal operation of the truck's other electrical components utilizes 12 V. How could the four batteries be connected to produce 24 V? To produce 12 V? Why is 24 V better than 12 V for starting the truck's engine (a very heavy load)?

21.3 Kirchhoff's Rules

19.

Can all of the currents going into the junction in Figure 21.44 be positive? Explain.

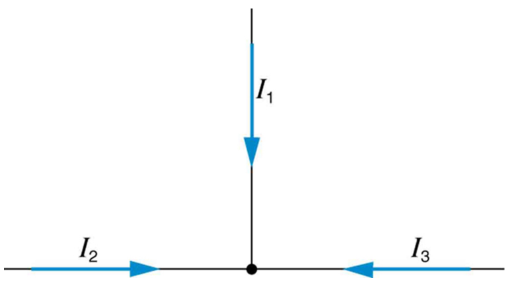

Figure 21.44

20.

Apply the junction rule to junction b in Figure 21.45. Is any new information gained by applying the junction rule at e? (In the figure, each emf is represented by script E.)

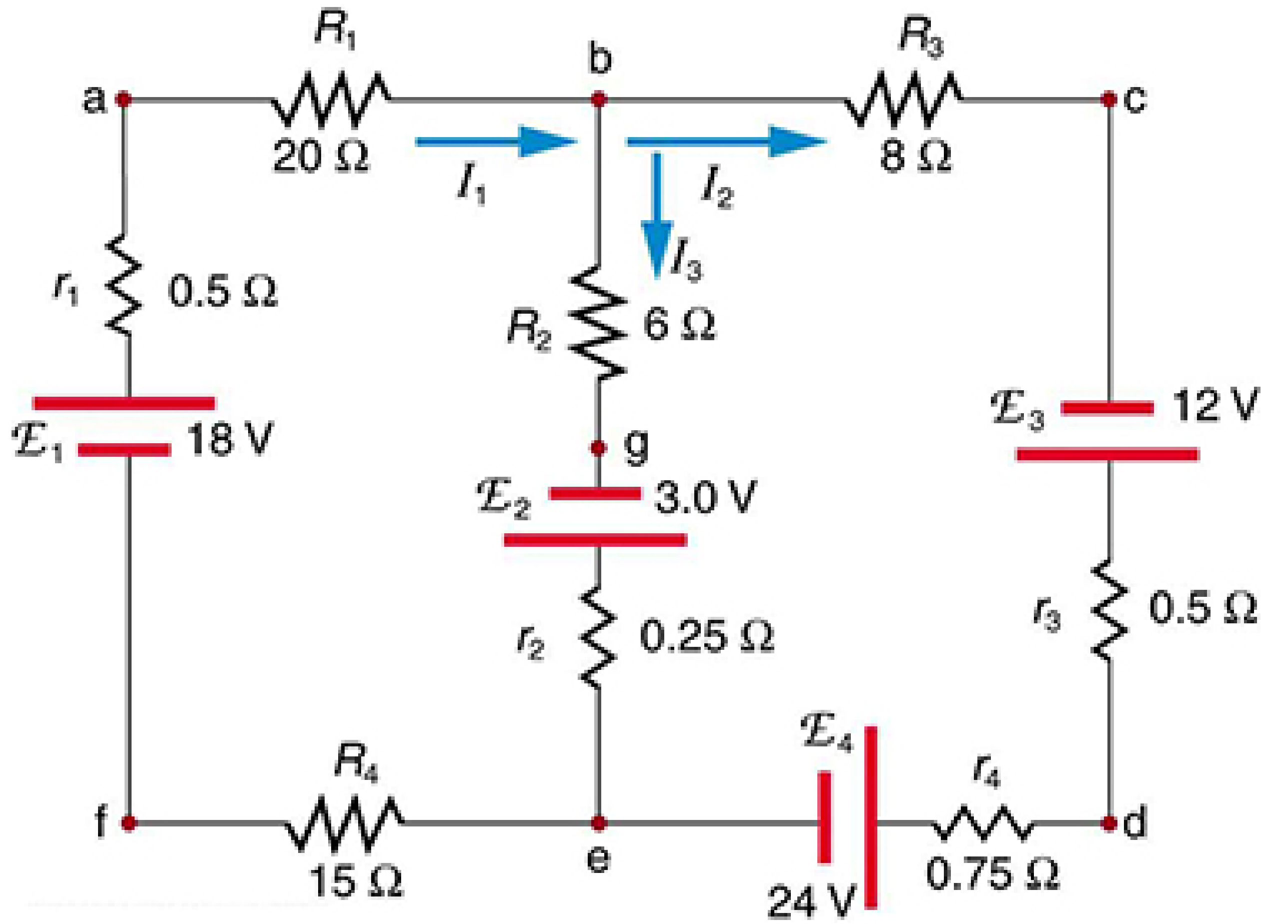

Figure 21.45

21.

(a) What is the potential difference going from point a to point b in Figure 21.45? (b) What is the potential difference going from c to b? (c) From e to g? (d) From e to d?

22.

Apply the loop rule to loop afedcba in Figure 21.45.

23.

Apply the loop rule to loops abgefa and cbgedc in Figure 21.45.

21.4 DC Voltmeters and Ammeters

24.

Why should you not connect an ammeter directly across a voltage source as shown in Figure 21.46? (Note that script E in the figure stands for emf.)

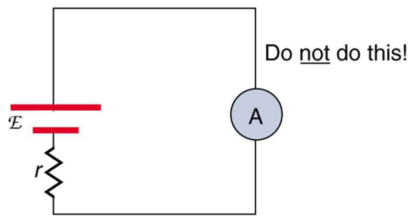

Figure 21.46

25.

Suppose you are using a multimeter (one designed to measure a range of voltages, currents, and resistances) to measure current in a circuit and you inadvertently leave it in a voltmeter mode. What effect will the meter have on the circuit? What would happen if you were measuring voltage but accidentally put the meter in the ammeter mode?

26.

Specify the points to which you could connect a voltmeter to measure the following potential differences in Figure 21.47: (a) the potential difference of the voltage source; (b) the potential difference across R_1; (c) across R_2; (d) across R_3; (e) across R_2 and R_3. Note that there may be more than one answer to each part.

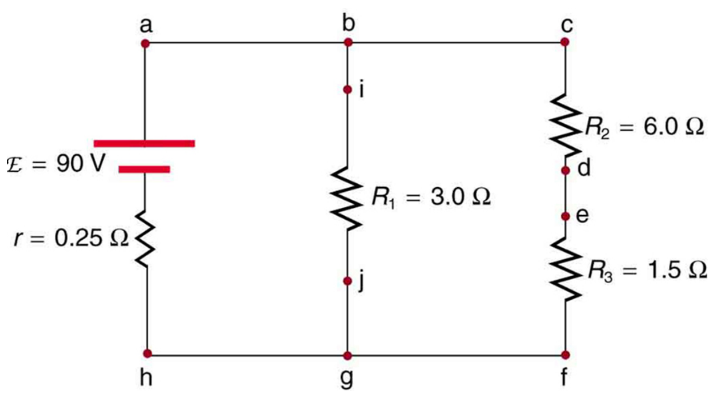

Figure 21.47

27.

To measure currents in Figure 21.47, you would replace a wire between two points with an ammeter. Specify the points between which you would place an ammeter to measure the following: (a) the total current; (b) the current flowing through R_1; (c) through R_2; (d) through R_3. Note that there may be more than one answer to each part.

21.5 Null Measurements

28.

Why can a null measurement be more accurate than one using standard voltmeters and ammeters? What factors limit the accuracy of null measurements?

29.

If a potentiometer is used to measure cell emfs on the order of a few volts, why is it most accurate for the standard emf_s to be the same order of magnitude and the resistances to be in the range of a few ohms?

21.6 DC Circuits Containing Resistors and Capacitors

30.

Regarding the units involved in the relationship $\tau = \text{RC}$, verify that the units of resistance times capacitance are time, that is, $\Omega \cdot F = s$.

31.

The RC time constant in heart defibrillation is crucial to limiting the time the current flows. If the capacitance in the defibrillation unit is fixed, how would you manipulate resistance in the circuit to adjust the RC constant τ? Would an adjustment of the applied voltage also be needed to ensure that the current delivered has an appropriate value?

32.

When making an ECG measurement, it is important to measure voltage variations over small time intervals. The time is limited by the RC constant of the circuit—it is not possible to measure time variations shorter than RC. How would you manipulate R and C in the circuit to allow the necessary measurements?

33.

Draw two graphs of charge versus time on a capacitor. Draw one for charging an initially uncharged capacitor in series with a resistor, as in the circuit in Figure 21.37, starting from t = 0. Draw the other for discharging a capacitor through a resistor, as in the circuit in Figure 21.38, starting at t = 0, with an initial charge Q_0. Show at least two intervals of τ.

34.

When charging a capacitor, as discussed in conjunction with Figure 21.37, how long does it take for the voltage on the capacitor to reach emf? Is this a problem?

35.

When discharging a capacitor, as discussed in conjunction with Figure 21.38, how long does it take for the voltage on the capacitor to reach zero? Is this a problem?

36.

Referring to Figure 21.37, draw a graph of potential difference across the resistor versus time, showing at least two intervals of τ. Also draw a graph of current versus time for this situation.

37.

A long, inexpensive extension cord is connected from inside the house to a refrigerator outside. The refrigerator doesn't run as it should. What might be the problem?

38.

In Figure 21.40, does the graph indicate the time constant is shorter for discharging than for charging? Would you expect ionized gas to have low resistance? How would you adjust R to get a longer time between flashes? Would adjusting R affect the discharge time?

39.

An electronic apparatus may have large capacitors at high voltage in the power supply section, presenting a shock hazard even when the apparatus is switched off. A "bleeder resistor" is therefore placed across such a capacitor, as shown schematically in Figure 21.48, to bleed the charge from it after the apparatus is off. Why must the bleeder resistance be much greater than the effective resistance of the rest of the circuit? How does this affect the time constant for discharging the capacitor?

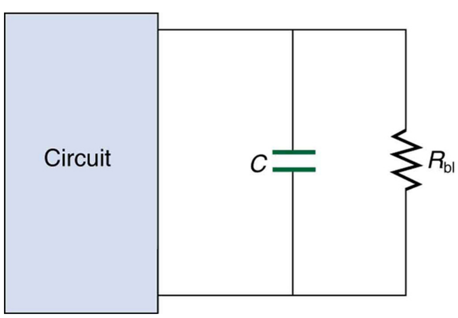

Figure 21.48 A bleeder resistor R_{bl} discharges the capacitor in this electronic device once it is switched off.