

Answer to Essential Question 18.2: To cause the electron to drift to the right, as shown, the electric field must be directed to the left. Because the electron has a negative charge, the force it feels is opposite in direction to that of the electric field. Electric field points in the direction of decreasing potential, so the right end of the wire must be at a higher potential.

18-3 Circuit Analogies, and Kirchoff's Rules

Analogies can help us to understand circuits, because an analogous system helps us build a model of the system we are interested in. For instance, there are many parallels between fluid being pumped through a set of pipes and charge flowing around a circuit. There are also useful parallels we can draw between a circuit and a ski hill, in which skiers are taken to the top of the hill by a chair lift and then ski down via various trails. Let's investigate these in turn.

A particular fluid system is shown in Figure 18.5. The fluid is enclosed in a set of pipes, and a water wheel spins in response to the flow. The fluid circulates through the system by means of a pump, which creates a pressure difference (analogous to potential difference in the circuit) between different sections of the system.

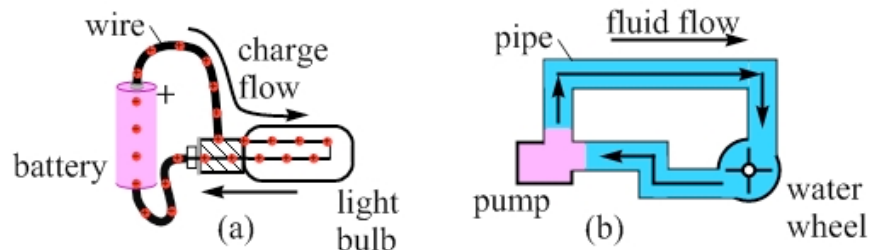


Figure 18.5: Fluid flows through a set of pipes like charges flow through a circuit.

The pump in the fluid system is like the battery in the circuit; the water is like the charge; and the water wheel is like the light bulb in the circuit. The large pipes act like the wires, one pipe carrying water from the pump to the water wheel, and another carrying the water back to the pump, much as charge flows through one wire from the battery to the light bulb, and through a second wire back to the battery. The pressure difference in the fluid system is analogous to the potential difference across the resistor in the circuit.

EXPLORATION 18.3 – Analogies between a circuit and a ski hill

A basic ski hill consists of a chair lift, like that shown in Figure 18.6, that takes skiers up to the top of the hill, and a trail that skiers ski down to the bottom. A short and wide downward slope takes the skiers from the top of the lift to the top of the trail, and another takes the skiers from the bottom of the trail to the bottom of the lift.

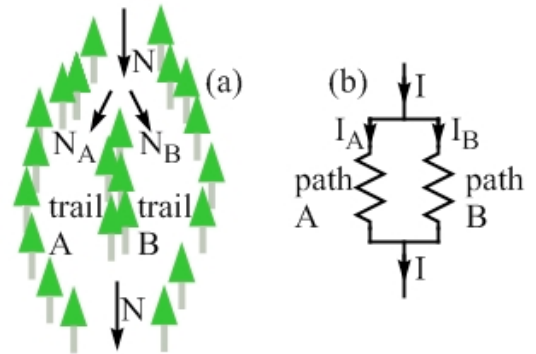
Step 1 – Identify the aspects of the circuit that are analogous to the various aspects of the ski hill. In particular, identify what for the ski hill plays the role of the battery, the flowing charge, and the resistor. The chair lift is like the battery in the circuit, while the skiers are like the charges. The chair lift raises the gravitational potential energy of the skiers, and the skiers dissipate all that energy as they ski down the trail (which is like the resistor in the circuit) to the bottom. Similarly, the battery raises the electric potential energy of the charges, and that energy is dissipated as the charges flow through the resistor.



Figure 18.6: A chair lift taking skiers up a hill. Photo credit: PhotoDisc/Getty Images.

Step 2 – Does the analogy have limitations? Identify at least one difference between the ski hill and the electric circuit. What happens when the chair lift / battery is turned off? On the ski hill the skiers keep skiing down to the bottom, but in the circuit if a switch is opened the net flow of charge stops. This difference stems from the fact that with the ski hill the potential difference is imposed by something external to the system, the Earth’s gravity, while in the circuit the battery provides the potential difference. Another difference is that in the circuit the charges are identical and obey basic laws of physics, while on a ski hill the skiers are not identical, and make choices regarding when to stop for lunch or to enjoy the view, and which route to take down the hill.

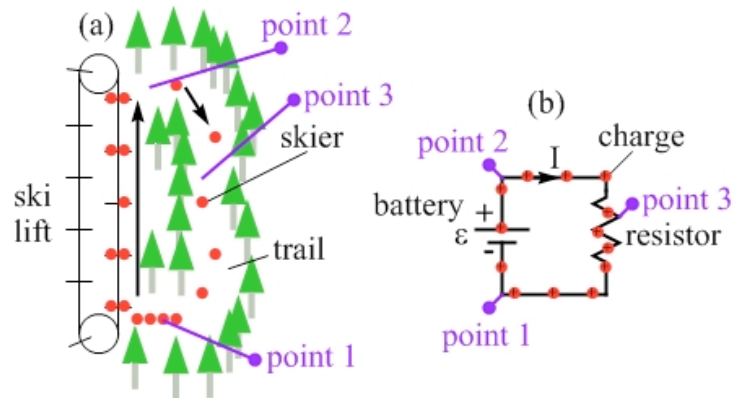
Step 3 - Let’s use our ski hill analogy to understand two basic rules about circuits, which we will make use of throughout the rest of the chapter. Figure 18.7 shows one ski trail dividing into two, trails A and B. The same thing happens in a circuit, with one path dividing into paths A and B. **What is the relationship between N , the total number of skiers, and N_A and N_B , the number of skiers choosing trails A and B, respectively? What is the analogous relationship between the current I in the top path in the circuit, and the currents I_A and I_B in paths A and B?**



We do not lose or gain skiers, so some skiers choose trail A and the rest choose B, giving $N = N_A + N_B$. The skiers come back together when the trails re-join, and N skiers continue down the trail. Similarly, a certain number of charges flow through the top path in the circuit, and the charges take either path A or path B through the circuit before re-combining. The rate of flow of charge is the current, so we can say that $I = I_A + I_B$. This is the **junction rule**.

Figure 18.7: (a) One trail splits temporarily into two on the ski hill; (b) one path splits into two in the circuit.

Step 4 - Figure 18.8 shows various points on a ski hill and in a circuit. For a complete loop, say from point 3 back to point 3, if we add up the changes in gravitational potential as we move around the loop, what will we get? If we do the analogous process for the circuit, adding up the electric potential differences as we move around a complete loop, what will we get?



In both cases we get zero. There is as much up as down on the ski hill, so when we return to the starting point the net change in potential is zero. The same applies to the circuit. This is the **loop rule**.

Figure 18.8: Equivalent points marked on a ski hill and on a circuit.

Key Ideas for Analogies: Analogies, particularly the gravitation-based ski-hill analogy, can give us considerable insight into circuits. In this case we used the analogy to come up with what are known as Kirchoff’s Rules. The **Junction Rule** – *the total current entering a junction is equal to the total current leaving a junction*. The **Loop Rule** – *the sum of all the potential differences for a closed loop is zero*. **Related End-of-Chapter Exercises: 1 and 2.**

Essential Question 18.3: In Figure 18.7, let’s say the resistance of path A is larger than that of path B. Which current is larger? What is the blanket statement summarizing this idea?