



Figure 1.12 How the magnetic attraction between parallel currents arises. (a) Idealized parallel conductors that contain equal numbers of positive and negative charges. (b) When the conductors carry currents, the spacing of their moving charges undergoes a relativistic contraction as seen from the laboratory. The conductors attract each other when i_I and i_{II} are in the same direction. (c) As seen by a negative charge in I, the negative charges in II are at rest whereas the positive charges are in motion. The contracted spacing of the latter leads to a net positive charge in II that attracts the negative charge in I. (d) As seen by a positive charge in I, the positive charges in II are at rest whereas the negative charges are in motion. The contracted spacing of the latter leads to a net negative charge on II that attracts the positive charge in I. The contracted spacings in b, c, and d are greatly exaggerated.

with charge invariance? The answer is that we must consider the entire circuit of which the conductor is a part. Because the circuit must be closed for a current to occur in it, for every current element in one direction that a moving observer finds to have, say, a positive charge, there must be another current element in the opposite direction which the same observer finds to have a negative charge. Hence magnetic forces always act between different parts of the same circuit, even though the circuit as a whole appears electrically neutral to all observers.

The preceding discussion considered only a particular magnetic effect. All other magnetic phenomena can also be interpreted on the basis of Coulomb's law, charge invariance, and special relativity, although the analysis is usually more complicated.