4-9 TABLE OF CONDUCTIVITIES

The conductivities σ (for direct current) of some common materials are listed in Table 4-1 for a temperature of 20°C and for a superconductor at temperatures below 21 K. See page 123.

4-10 KIRCHHOFF'S VOLTAGE LAW AND THE DIFFERENCE BETWEEN POTENTIAL AND EMF

Consider the simple electric circuit shown by the schematic diagram in Fig. 4-9. The circuit consists of a resistor R_0 and the battery. The current is I at all points in the circuit. At any point in the conducting material of the circuit we have from Ohm's law at a point that $\mathbf{J}/\sigma = \mathbf{E}$, where $\mathbf{E}$ is the total field at the point.

In general the total field $\mathbf{E}$ may be due not only to static charges but also to other causes such as the chemical action in a battery. To indicate this explicitly, we write

$$\mathbf{E} = \mathbf{E}_c + \mathbf{E}_e \tag{1}$$

where $\mathbf{E}_c$ = static electric field due to charges; the subscript c indicates explicitly that the field is due to *charges*

$\mathbf{E}_e$ = electric field generated by other causes as by a battery; the subscript e indicates explicitly that it is an *emf-producing* field

Whereas $\mathbf{E}_c$ is derivable as the gradient of a scalar potential due to charges ($\mathbf{E}_c = -\nabla V$), this is not the case for $\mathbf{E}_e$. Substituting (1) in (4-7-2), writing $\mathbf{J} = \mathbf{I}/a$, where a is the cross-sectional area of the conductor, and noting the value of σ from (4-6-2), we have

$$\frac{\mathbf{J}}{\sigma} = \mathbf{I}\frac{R}{l} = \mathbf{E}_c + \mathbf{E}_e \tag{2}$$

where R/l is the resistance per unit length in ohms per meter. This applies at any point in the circuit. Integrating around the complete circuit gives

$$\oint \mathbf{E}_c \cdot d\mathbf{l} + \oint \mathbf{E}_e \cdot d\mathbf{l} = I \oint \frac{R}{l}\, dl \tag{3}$$

The first term is zero; i.e., the line integral of a field due to charges is zero around a closed circuit (see Sec. 2-8, last paragraph). However, the second term involving the line integral of $\mathbf{E}_e$ around the circuit is not zero but is equal to a voltage called

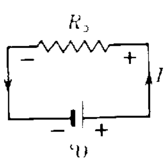

Figure 4-9 Series circuit of battery and external resistance.