15.7: EMF and Scalar Potential

The EMF ΔV has the same units as the scalar potential ϕ. What is the difference between the two quantities? Both are related to the work done per unit charge by the electric field on a particle moving through the field. However, recall that the electric field is composed of two parts:

$$\mathbf{E}=-\left(\frac{\partial \phi}{\partial x}, \frac{\partial \phi}{\partial y}, \frac{\partial \phi}{\partial z}\right)-\frac{\partial \mathbf{A}}{\partial t} \tag{15.7.1}$$

$\Delta \phi=\phi_{2}-\phi_{1}$ is minus the work done on the particle in going from point 1 to point 2 by the part of the electric field associated with the scalar potential; moving to a lower potential results in a release of kinetic energy according to the conservation of energy. On the other hand, $\Delta \mathrm{V}$ is (plus) the work done per unit charge on a particle by the part of the electric field associated with the time derivative of the vector potential.

Aside from the different sign conventions, there is one other fundamental difference between the two quantities: $\Delta \phi$ is always zero for closed paths, i. e., paths in which the particle returns to its initial point. This is because point 1 is then the same as point 2, so $\phi_{1}=\phi_{2}.$. This condition doesn't necessarily apply to the EMF. $\Delta \mathrm{V}$ often is non-zero for closed particle paths. The electric generator that we have just discussed is an important case in point. The total work done per unit charge by the electric field on a charged particle moving along some path is thus $\Delta \mathrm{V}-\Delta \phi.$ The $\Delta \phi$ term drops out if the path is closed.