

# Transformed E&M I materials

## Potential (Griffiths Chapter 2)

---

### STUDENT DIFFICULTIES

#### What is V? (\*\*\*)

- Even the best students don't have a solid conceptualization of what V means – they do not relate it easily to force or work and some have forgotten what work is, how to find it, what its units are. We spend a lot of time *calculating* V and seem to lose sight of the *meaning* of V. Using the “Square of Electricity” (see Activities/Activity Resources in course files) may be one way to address this difficulty. This would make an excellent whiteboard activity.
  - Relating to this, students have difficulty accessing the most effective tool to calculate the potential. They often fall back on calculating E to determine V even when a direct calculation of V is much easier. This may be because, as Griffiths presents E first, they consider it to be more fundamental and are more comfortable with it.
- Only some students use test charges to check whether the sign of the potential works, and most have trouble remembering which direction a test charge would go.
- Some students, when presented with  $\int E \cdot dl = ?$  out of context of the chapter did not recognize this as the formula for V though some recognized it after spending some time with it.
- Many students have a hard time which of the many equations for potential will be most effective for calculating the potential.

#### V arises from a conservative E field, Curl of E (\*\*)

- When looking at the equation  $\nabla \times E = 0$ , most students do not see a connection to voltage V unless prompted. When attempting to explain what a conservative field means, most draw a loop and say that you have to get back to the same value that you started at, but they are not clear on *what* has to add up to zero around that closed loop (i.e., E dotted with dl).
- Only the very best students are able to connect the curl of E with our ability to define a scalar potential. I was able to “trick” many students by asking them why  $\int E \cdot dl = 0$ . Most puzzled about it for a long time and did not eventually recognize this as an incorrect statement, though the best students did reply in consternation that they didn't think that was true.

- When using this form to calculate the potential, students have difficulties determining the limits of integration and connecting them to the physical situation. See the Math Resources doc for more on student difficulties with line integrals.

### **Reference point (\*\*)**

- Many students have trouble choosing a suitable reference point for the potential. On a post-test, many struggled with what to do if the reference point ( $V=0$ ) was set at the center of a charged sphere, rather than at infinity. The ones who were able to correctly reason generally gave work-related arguments, but many failed to do so, underlining the difficulty with relating work and potential.
- Some students have a hard time with the arbitrary nature of  $V$ . In addition to having difficulties picking a reference point, there are students who state that  $\Delta V$  is also arbitrary in sign, depending on where you put zero.

### **Direct integration to find V**

- Students seemed to “forget” Gauss’ Law once given the integral formulation for  $V$ , and need to be reminded that Gauss’ Law is still easiest in cases of symmetry (and you can then find  $V$  from  $E$ ).
  - Some students have the opposite problem and (as with calculating  $E$ ) they will try to use Gauss’ law in situations where there is not enough symmetry (i.e. non uniform charge distributions).