Elec-a-tri-ci-ty and-a Mag-a-ne-tism

(A Course Review)

1. Now I had a little mouse, in a spherical house—and he was not very large.
   And my little mouse, he knew all about Gauss, so he carried an electronic charge.
   He could calculate the integral of **E** dot **dS**, over the surface of his sphere—
   And set it equal to the charge inside, divided by epsilon zere. . . . . oh.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm*
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

2. Now the electron's charge is not very large when measured in the units that we know.
   And much to our surprise, the charge is quantized with a quantum that Millikan did show
   Was minus one point six times ten raised to — the power of minus nineteen—
   Coulombs, that is. In the E and M biz, no smaller has ever been seen.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

3. Now it's time to review that near a charge *q* there's something considered essential:
   You'll survive if you can derive the electrostatic potential.
   Integr<u>ate</u> the vector field from point *A* to point *B*, to get the <u>po</u>tential† <u>diff</u>erence delta *V*.
   And recall that delta *V* is a scalar quantity—it's a measure of po<u>ten</u>tial energy.
   (spoken: per unit charge.)

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

4. Now the capacitor—what is it for?—it will store electrostatic energy.
   It highly concentrates, in the space between the plates, the electrostatic field, we call it **E**.
   Take the charge *q* and divide by delta *V*, and you will have the capacity *C*.
   The capacitor—that's what it's for—it will store electrostatic energy.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

5. Now it may seem unreal, but the magnetic field results from special <u>rel</u>ativi<u>ty</u>.
   We know how to prove that when a charge moves, that there's another field—we call it **B**.
   And when a charge *q* moves through a B-field of course we can calculate the Lorentz Force:
   It's *q* times **v** crossed into **B**, a result of special <u>re</u>lativi<u>ty</u>.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

6. Now we take a little hoop and make a current loop: It's a dipole, with magnetic moment **mu**.
   It's very ea<u>sy</u> to calcul<u>ate</u> the *B* sub <u>*z*</u>—it takes just a moment or two.
   If we choose, we may use the formula of Biot and Savart—
   The magnetic field **B** along the axis *z* drops off like the inverse cube of *r*.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

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* Emphasize the consonents in "E-lec-a-tri-ci-ty" (like sparks), and hum the end of "Mag-a-ne-tism" (like a transformer).

† In a few cases, words may fit the meter better if the underlined syllable is stressed.

7. Now where, oh where, is the Law of Ampère? In the text, on page six ninety-three.
   As we shall see, we can calculate **B** for cases of high symmetry.
   We can calculate the integral of **B** dot **dl**, and we'll have no trouble with the math.
   The result ought to be *I* times **mu** naught, with *I* inside the integration path.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

8. Now the next thing that we saw was Faraday's Law of electromagnetic induction.
   It's now in use to generate the juice for electrical power production.
   Differentiate the flux with respect to *t* to get the electromotive force—
   So when we watch our TV, and when we pay P.G.&E, we'll remember what we learned in this course.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

9. Now I had an alligator who swallowed an oscillator, so he had some inductance and capacitance.
   And then a little later, he swallowed a generator, and he drove that circuit into resonance.
   He was so great, he would oscillate, with a little *LdI/dt;*
   He'd a very high *Q*, just like me and you—yes my alligator he had Quality.

   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
   Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

10. Now at last, we shall tell the tale of Maxwell—he wrote it down in eighteen seventy-three.
    In only four relations, now called Maxwell's equations—on the blackboard for everyone to see.
    They link the fields to each other, and to the current and the charge—
    From the curl and the divergence, we find complete emergence of the electromagnetic theory.

    Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm
    Elec-a-tri-city and-a-Mag-a-ne-tismmmmmmmmm

Maxwell's Equations*

$\operatorname{div}\mathbf{E} = \nabla\cdot\mathbf{E} = \dfrac{\rho}{\varepsilon_0}$	Gauss's Law
$\operatorname{div}\mathbf{B} = \nabla\cdot\mathbf{B} = 0$	Gauss's Law for magnetism (no magnetic charge)
$\operatorname{curl}\mathbf{E} = \nabla\times\mathbf{E} = -\dfrac{\partial\mathbf{B}}{\partial t}$	Faraday's Law of induction
$\operatorname{curl}\mathbf{B} = \nabla\times\mathbf{B} = \dfrac{\mathbf{j}}{c^2\varepsilon_0} + \dfrac{1}{c^2}\dfrac{\partial\mathbf{E}}{\partial t}$	Ampère's Law plus the Maxwell addition

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$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B})$ The Lorentz Force Law

Try to memorize this song, and practice singing it, either by yourself or with others. Practice getting the stressed syllables (some are underlined like this) to coincide with the notes. (They are very exact.) Note that the chorus lines end musically on a dominant seventh, and therefore so does the song. In western musical culture, this is an indication that there is more to come, and that the story is not ended. This is true not only with electricity and magnetism, but with all of physics.

This song may be grabbed from https://scott.physics.ucsc.edu/songs/e_and_m/.

* See The Feynman Lectures on Physics, Volume II, Page 18-2.

E-lec-a-tri-ci-ty and-a Mag-a-ne-tism

* Emphasize the consonants in "E-lec-a-tri-ci-ty" (like sparks), and hum the end of "mag-a-ne-ti-sm" (like a transformer)