Objective: to use software to simulate electromagnetic fields, to explore graphically the electric fields produced by various spatial distributions of charges, and to investigate Gauss’s law.

Preparation: Start, All Programs, EM Field 6, EMField
Authors: ______________________________________________________

Define: Electric field \( E(r) \):

Define algorithm:

For a single charge, strength of the electric field = \( E (r) = \)

Define Equi-potential line:

I. Single Point Charge
   a) We will investigate a single positive charge and its electric field vectors.
      Prediction of field vectors:

      Make the window full screen.
      Pull down Sources, 3D Point Charges.
      Now drag a charge of +1 onto the stage (playing field).
      Pull down Field and Potential, Field Vectors
      Click at many various points around your charge.
      Sketch the program’s field vectors:

      Compare your prediction and the program’s result:

      Select Display, Clean up screen.

   b) We will investigate a single positive charge and its electric field lines.
      Predict the field lines:

      Select Field and Potential, Field Lines.
      Click at various points around your charge.
      Sketch of program’s electric field lines:
      How does your prediction compare with the program?

      Display, Clean up screen.
c) We will investigate a single positive charge and its electric directional arrows.
Field and Potential, Directional arrows:
Click at various points around your charge.
Sketch of program’s electric directional arrows:

Describe the differences between electric field vectors, lines, and directional arrows:

d) Now we will investigate a single negative charge and its electric field vectors.
Prediction of field vectors:

Clean up the display, and place the charge.
Select Field and Potential, Field Vectors
Click at various points around your charge.
Sketch of program’s field vectors:

Try a larger negative charge:

Describe how the field vectors of a negative charge are different from those of a positive charge.

II. Two charges on the stage
Display, Clean Up Screen
a) Investigate one positive charge = 1, and one negative charge = -1, a few centimeters apart.
Prediction of field vectors:

Sketch of program’s field vectors:
Try click and hold and drag.
Then add field lines also.
Comment on the relationship of field lines and field vectors:

b) Try charges +1, +1
Prediction of field lines:
Sketch of program’s field lines:

III. Three Charges on the stage
a) Investigate +1, +1, +2 in a straight line
Prediction of electric field lines:

Sketch of program’s electric field lines:

b) Try +1, -1, +2 in a straight line
Prediction of field lines:

Put in lots of field lines.
Sketch of program’s field lines:

State an algorithm for drawing field lines:

c) Drag one of the charges to another position on the stage, off the straight line.
Prediction of field vectors:

Sketch of program’s field vectors:
Isn't this fun?
IV. Equipotential Surfaces
What is the relationship of equipotential surfaces to field lines?

What unit is electric potential measured in?

a) Single Point Charge
Prediction of equipotentials:
Select Field and Potential, Field lines, and place some field lines.
Select Field and Potential, Equipotentials.
Click at various points around your charge to place the equipotential lines.
Sketch of program’s equipotentials:

b) Now let’s get quantitative.
Display, Clean up screen.
Show grid. Place a charge of +6 exactly on a grid point.

We want to find out how equipotential values depend on distance from a charge.
Select Field and Potential, Equipotentials with numbers.
Now think before you click. Use the grid, and click intelligently.

Print the program’s graphic of equipotentials with numbers (one copy for your team).
Record your data of distance from the charge, and equipotential values in a spreadsheet.
In particular, what is the value of the potential at a distance of one grid point? _________

So, what is the value of k in this EMField computer program? _________

Make a scatter point graph of potential value vs. distance (x axis).
Is this relationship monotonic? _________ Is it linear? _________
Try fitting various trendlines. For each type of trendline record the R squared value. Higher numbers of R squared indicate a better fit of the trendline to the data. Make a small table in your spreadsheet for the type of trendline (linear, exponential, logarithmic, polynomial, power law) and the corresponding R squared value. Choose the best trendline and leave it on the graph, while deleting the other trendlines.
Write the best equation:

After using print preview, print the spreadsheet with its small embedded graph.

V. Charged Rods (infinitely long, coming out of the screen)
a) Sources, 2D Charged Rods
+1, +2
State Gauss’s Law:
Field and Potential, Flux and Gauss’s Law
Drag “a circle” (a closed curve not crossing itself) around one of the rods. This is a gaussian cylinder.
Drag another closed curve around the other rod.
Drag another curve around both rods.
Drag another curve around empty space.
Describe the display:

b) Sources, 2D charged rods
+2, -2
Drag the four curves and describe:

VI. Line Currents
Electric currents in wires cause magnetic fields.
Prediction:

Display, Show grid.
Display, Constrain to grid.
a) sources, +1 amp current
Drag to see the magnetic field vectors
Sketch:

b) +1 amp, +1 amp currents
Sketch of program’s magnetic field lines:

VII. Ready to test what you have learned? Get ready for a challenge!
Select Sources, 3D point charges
Option, Challenge game
a) Find one hidden charge by clicking to expose electric field vectors. (Recall page 1.)
When you are confident that you have located a charge, drag an open circle marker to its position.
Challenge, Estimate amount of charge.
(Hint: think about the length of the electric field vector at a specific distance from a charge.)
Click on the marker and type your magnitude estimate. Challenge, Judge. Were you correct? _____
Describe your method:

b) Option, Challenge game. Find two hidden charges

Conclusions and future work using this technique: