

# Week 7 Challenge Homework

## Electric Potential and Resistive Circuits

**Submission Details** | Submit a digital copy (PDF, jpg, etc.) to Canvas. Include solutions to the metacognitive exercise and each question. Please use the interface to associate each page of your submission with the assignment. It makes grading much easier. Please clearly indicate which question is being solved. If data is needed to complete a problem, be sure to cite the source you've acquired your data from. Typed work will not receive credit. See the course website for further details.

**Group Submissions** | You may submit a group collaboration to Canvas. Add each group member to the submission. Each group member should contribute to the work. Clearly indicate which part of the submission is written by each member (color or labels are preferable).

**Sensemaking** | You will be asked to apply sensemaking in some problems. More information about sensemaking can be found on the BoxSand [Sensemaking](#) page, which is linked on the Canvas homepage.

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### Metacognitive Exercise

Each week will feature a metacognitive exercise, followed by one or two challenge problems to solve. The metacognitive exercise will usually ask you to reflect on your solution to the previous week's challenge problems.

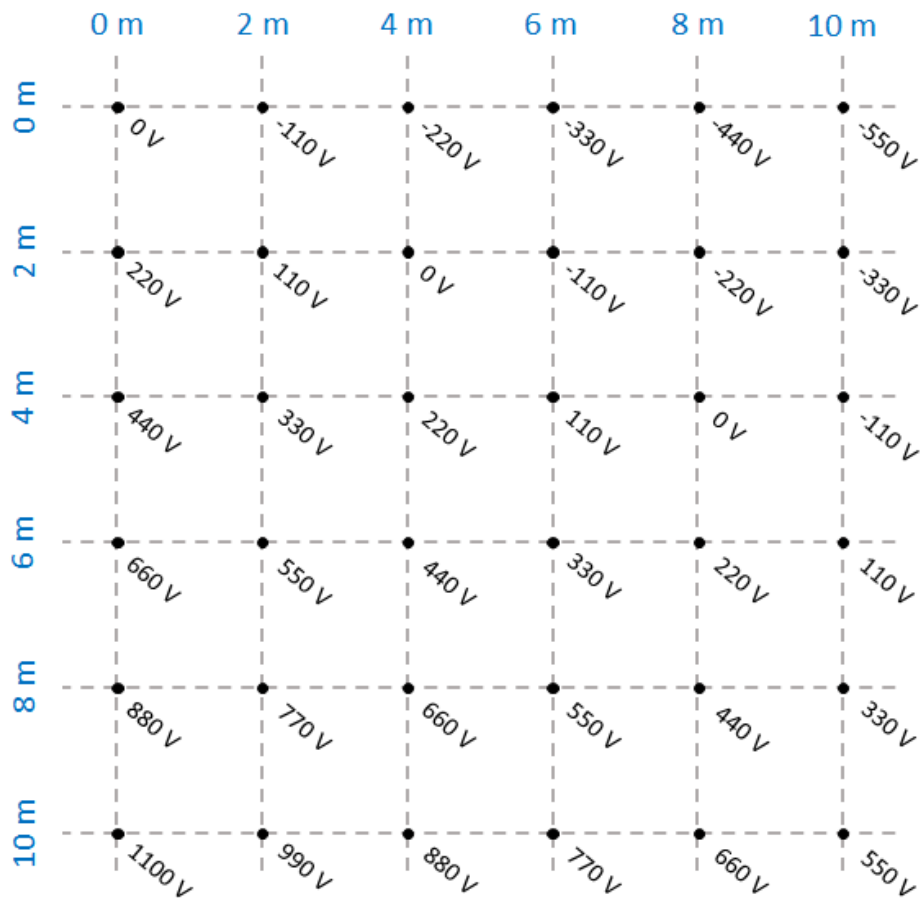
Review your solution to the Week 6 Challenge Homework. If you do not have a copy of it anymore, you can find it on Canvas or Gradescope, under the Week 6 Challenge Homework assignment. Also, review the solution which has been posted to the BoxSand solutions archive ([click here for a link](#)). Solutions are posted a few days after the assignment is due.

- (a) Review your own work on the previous midterms. How often do you draw physical representations (diagrams with physics information on them) when solving problems on exams? What thoughts and/or feelings do you have about physical representations in the context of physics problem solving?

### Question 1

The electric potential is mapped out everywhere in a 2D-space for a certain distribution of charge. Please be clear and precise with your solutions to the following questions.

- Draw a set of equipotential lines for  $V = -400\text{V}, -100\text{V}, 200\text{V}, 500\text{V}, 800\text{V}$  and  $1100\text{V}$ .
- Using the vector field representation, sketch the electric field in this region.
- Find an algebraic equation for the **scalar** electric potential as a function of  $x$  and  $y$ .
- Find an algebraic equation for the **vector** electric field as a function of  $x$  and  $y$ .
- Using the *self-consistency* sensemaking technique, predict from your answer to part (d) what you would expect the spacing (how many meters between the listed values in the vertical or horizontal direction) of the equipotential lines to be (and explain why). Compare this prediction to what you found in part (a).



## Question 2

Certain fish, such as the Elephant Fish (Mormyridae), concentrate charges in their head and tail, thereby producing an electric field in the water around them. This field creates a potential difference of a few volts between the head and tail, which in turn causes current to flow in the conducting seawater. As the fish swims, it passes near objects that have a resistivity different from that of seawater, which in turn causes the current to vary. Cells in the skin of the fish are sensitive to this current and can detect changes in it. The changes in the current allow the fish to navigate. (In the next few chapters, we shall investigate how the fish might detect this current.)



Since the electric field is weak far from the fish, we shall consider only the field in the vicinity of the fish. If the fish is 20 cm long (certain members of the family can reach 1.5 m), we can model the seawater through which that field passes as a conducting tube around the fish of area  $4.0 \text{ cm}^2$  which has a potential difference of 3.0 V between its ends. The resistivity of seawater is  $0.13 \text{ } \Omega \cdot \text{m}$ . For this model let's assume that the fish has negligible width so that it does not affect the conductivity of the tube.

- (a) How large is the current through the tube of the seawater?
- (b) Suppose the fish swims along the side of a vertical rock face such that one quarter of the tube is now taken up by the rock. The rock has a metal content that gives it twice the conductivity of seawater. What is the difference in current that the fish detects? (Hint: How are the rock and the remaining water in the tube connected, in series or in parallel?)
- (c) Use known value sensemaking to evaluate your answer to part (b). Make a prediction for whether the current should increase or decrease. Explain your prediction using conceptual arguments. Finally, compare your prediction with your found answer to part (b), does they agree?