

Physics Invention Sequences Users' Guide: Capacitance

CAPACITANCE INVENTION SEQUENCE

Includes: *charge storage index* (capacitance)

Teacher Notes: Electric charge is a property of matter that is abstract to most students. When reasoning about more abstract quantities, students often revert to more procedural and less sensemaking ways of thinking. So even though it may seem that this exercise is exactly the same as what they have done in mechanics, the context itself makes it a completely different task for students.. Capacitance is especially challenging as a physical quantity and most students do not have a qualitative sense of what it tells us about an object. There is also additional information here so the students have to decide which quantities matter in creating an index, which makes this activity quite challenging.

Levels: This sequence is appropriate for college level and any advanced HS course that teaches capacitance.

Charge Storage Index

You are designing a new generation of phone chargers, and as part of the design you need some way of temporarily storing charge. You try the four devices below attaching a couple of different batteries to each one (one at a time), and for each device you measure (a) the battery voltage; (b) the amount of charge stored on each device; and (c) the amount of energy each one stores. Your results are shown in the table below.

<i>Device name</i>	<i>Battery Voltage</i>	<i>Charge Stored</i>	<i>Energy Stored</i>
Charge Master	24 Volts	10 micro-Coulombs	0.120 milliJoules
Charge Master	120 Volts	50 micro-Coulombs	3 milliJoules
Volt Miser	8 Volts	4 micro-Coulombs	0.016 milliJoules
Volt Miser	12 Volts	6 micro-Coulombs	0.036 milliJoules
Pack-a-Proton	3 Volts	1 micro-Coulomb	0.0015 milliJoules
Pack-a-Proton	9 Volts	3 micro-Coulombs	0.0135 milliJoules
Stor-a-Shock	60 Volts	28 micro-Coulombs	0.840 milliJoules
Stor-a-Shock	15 Volts	7 micro-Coulombs	0.0525 milliJoules

An **index** is a number that helps people compare things.

- *Miles per gallon* is an index of how well a car uses gas..
- *Batting average* is an index of how well a baseball player hits.
- *Grades* are an index of how well students perform on a test.

We want you to invent a procedure for computing an index that helps make comparisons between the devices shown. You want to choose the device that will allow you to store the most charge for a variety of phones that will use a variety of different batteries. Invent an index that will allow you to rank the devices from best to worst in terms of charge storage.

Rules for the Index

1. A single device gets a single index.
 2. You have to use the exact same procedure for each device to find its index.
 3. A big index value should mean that the device is better at storing charge. A small index value should mean that the device is not as good at storing charge.
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Explain why your index is a useful measure.

Follow up questions

1. How does the amount of energy stored by each device *depend on* the voltage applied? (If you double the voltage across the device, or triple it, or quadruple it, what happens to the energy stored? Does it also double, or triple...?)

2. How does the amount of energy stored by each device depend on the value of your index? (If the index is twice as big, or three times as big, etc., what happens to the amount of energy stored?)

3. Generate an equation that allows you to predict how much energy a capacitor will store based on the index value and the voltage of the battery to which it is attached. You should come up with a single equation that allows you to predict all of the energies in the table,