Practice Exam 1 for Physics 206/211 — Light and Matter, ch. 0-22

1 Measurements show that when a voltage difference of 38 mV is applied across a certain resistor, a current of 42 μA flows. Find the resistance.

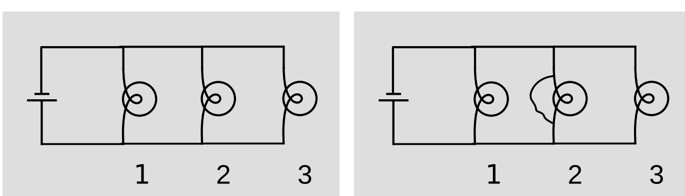
2 Each of the following statements shows a basic misconception about physics. Explain what is wrong with each one. You do not have to have any specialized knowledge about any of the devices or situations described. You do not necessarily need to rewrite the statements to make them correct, but that would be one very good way to show you understand what was wrong with them.
(a) In a complete circuit, voltage is able to flow all the way around to where it started.
(b) The heating element of an electric stove is a resistor. It gets hot because it has a lot of resistance.
(c) The electric company supplies power to my house through the wires strung between telephone poles. The system isn't perfectly efficient, so some charge is dissipated in the wires.

3 Three identical particles of charge q are fixed at three corners of a square with sides of length b. Find the magnitude of the electric field at the empty corner. Simplify your answer.

4 If you buy resistors from a store or a catalog, they are not actually available in every conceivable value. In the low kiloohm range, for example, the following values are ones that are most commonly manufactured: 1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, and 8.2 kΩ. When one needs some specific value of resistance that is not on the list, it becomes necessary to combine two or more resistors in some way so as to create the desired equivalent resistance. Suppose you have access to plenty of resistors in exactly the above values, but not in any other values. Find a way to make an equivalent resistance of about 1.3 kΩ. It doesn't have to be exact (the resistors have tolerance ranges anyway), but find a value that lies between 1.25 and 1.35 kΩ. (In real life, you would want to find the design that would use the minimum number of resistors, ideally just two. In this problem, however, feel free to use more if you find that easier.)

5 The three equations listed below all relate to the electric field. For each one, state whether it's a definition, and therefore always true, or whether it's only true under certain circumstances. If it's only true sometimes, explain the conditions under which it applies.
(a) $E = -\Delta V/\Delta x$
(b) $E = F/q$
(c) $E = kq/r^2$

6 The first figure, on the left below, shows a battery lighting three lightbulbs. In the second, right-hand figure, an extra wire has been added. Describe what happens when the extra wire is added.



Answer to problem 1
$R = (3.8 \times 10^{-2}\text{ V})/(4.2 \times 10^{-5}\text{ A}) = 900\ \Omega$.

Answer to problem 2
(a) Voltage doesn't flow anywhere. What flows is current.
(b) The heating element gets hot because it has a *low* resistance. The power dissipared in it is $P = IV = (V/R)V = V^2/R$, so a big resistance would give *less* power.
(c) Energy is dissipated (turned into heat energy). Charge can't be dissipated, because charge is conserved.

Answer to problem 3
Let positive x be to the right and positive y up, and let the square be aligned with the axes. Let the empty corner be the one on the lower left, and put this at the origin O. The contribution to the field at O from the lower right charge has components

$$E_{1x} = -kq/b^2 \qquad E_{1y} = 0.$$

The field from the upper left charge has

$$E_{2x} = 0 \qquad E_{2y} = -kq/b^2.$$

The diagonally opposite charge lies at a distance $\sqrt{2}b$, so the magnitude of its field at O is $E_3 = kq/2b^2$. The x and y components of this field are both $(-\cos 45\,^\circ)E_3$, so

$$E_{3x} = E_{3y} = -kq/2^{3/2}b^2.$$

Adding components gives a total field with components

$$E_x = E_y = -(kq/b^2)(1 + 2^{-3/2}).$$

Its magnitude is $|E| = \sqrt{F_x^2 + F_y^2} = (kq/b^2)(\sqrt{2} + 1/2)$.

Answer to problem 4
There are many possible ways of doing this, and finding one just takes a little trial and error. One possibility is to use three 3.9 kΩ resistors in parallel.

Answer to problem 5
(a) An expression of the form $\Delta \ldots/\Delta \ldots$ can be interpreted as the slope of a graph. A graph only has a single well-defined slope if the graph is a line, i.e., if its slope is the same everywhere. Thus this equation is valid only if the electric field is constant.
(b) This is the definition of the electric field, and is always valid (assuming q is small enough not to disturb the other charges that are creating the field).
(c) This is the equation for the field of a point charge. It's only valid for a point charge.

Answer to problem 6
In the modified circuit, all of the wires are connected, and therefore all of the wires are at the same voltage. There is no voltage difference across any of the bulbs, and all three bulbs go out. This is a short circuit, and it will kill the battery and get hot.