1. As freshly laundered clothes tumble about in a hot dryer, they rub against one another. Sliding friction transfers electric charges from one piece of clothing to the other so that some items become positively charged and others negatively charged. These charge accumulations produce static cling. As you unload the dryer you find several socks clinging to a shirt. How do the charges on the socks and shirt compare to one another?

- the socks carry an excess charge that is the same as that on the shirt
- the socks and the shirt both have neutral charge (no excess charges)
- the socks carry an excess charge that is the opposite of that on the shirt
- the socks and the shirt both have lots of excess charges with each having equal amounts of positive and negative charges

As you pull the socks away from the shirt at a constant velocity, you do work on the socks. Into what form of energy is your energy being transformed?

- kinetic energy
- thermal energy
- electrostatic potential energy
- pressure potential energy

If you let go, the sock is attracted back towards the shirt and sticks to the shirt. Just before the sock hits the shirt, the energy you added to the sock is now in what form?

- kinetic energy
- thermal energy
- electrostatic potential energy
- pressure potential energy

After the sock hits the shirt, the energy you added to the sock is in what form?

- kinetic energy
- thermal energy
After removing the socks from the shirt, you hold two socks next to each other. The socks:

- repel each other
- attract each other
- neither attract nor repel each other

Suppose that the socks are covered with positive charge. At 5 cm away from the shirt, the excess negative charge on the shirt attracts the sock with a certain amount of force. How does this attractive force change when the sock is twice as far (10 cm) from the shirt?

- the force is 4 times larger
- the force is 2 times larger
- the force is the same
- the force is half as large
- the force is a quarter as large

The electrostatic force is an inverse square law, $F = k\frac{q_1 q_2}{r^2}$.
If we double the distance, the force decreases by a factor of four.

Two magnets are placed such that the like poles are separated by 2 mm of empty space. The force felt by one is 10 N. If they are further separated so the distance between them is 1 m, what is the magnitude of the force?

- 40 N.
- $4 \times 10^{-5}$ N.
- Less than 40 N, but bigger than $4 \times 10^{-5}$ N.
- greater than 40 N.
- less than $4 \times 10^{-5}$ N.

The force between two magnetic poles falls off as an inverse square law, but magnets always have two poles, and when they are far away from each other the force between them falls off faster than an inverse square.
2. You are inventing an improved paint sprayer for painting lines on the road. A paint sprayer sends out little droplets of paint that cover the surface. With a conventional sprayer these can pile up on top of each others, so to ensure that all the surface is covered you have to put down more than is necessary at some places. This wastes about half of the paint, and you need to figure out how to make sure the paint only goes down on the unpainted road surface rather than piling up on top of paint that came out earlier. You get the idea of putting electric charges on the little droplets of paint so they will repel each other. Of course gravity is trying to pull the droplet of paint down on top of a previous drop, so what you want to make sure that the force of gravity on a droplet of paint is equal to the repulsive force between two droplets when the droplets are about 1.5 droplet diameters apart (center-to-center). That will make them land just next to each other to give a nice uniform layer but not pile up one on top of the other (SEE DRAWING). With a little research you find out that the droplets of paint produced by the first sprayer you try are spheres about the diameter of a human hair (So diameter = 0.00006 m) and they have the same density as water. Now you have enough information to design a paint sprayer that will save millions of dollars on highway painting costs every year and make you fabulously wealthy. Below we will break the problem down into several steps that you need to work through. (Hint: the volume of a sphere is \(\frac{4}{3} \pi r^3\))
What is the mass of each droplet?
\[ m = \rho V = 1000 \text{ kg/m}^3 \times \left(\frac{4}{3}\pi r^3\right) = 1.13 \times 10^{-10} \text{ kg} \]

What is the gravitational force on a droplet of paint?
\[ F_g = mg = 1.13 \times 10^{-10} \text{ kg} \times 9.8 \text{ m/s}^2 = 1.1 \times 10^{-9} \text{ N} \]

You run the drops through a region of corona discharge and each drop picks up a charge of \(1.4 \times 10^{-11}\) Coulombs.
The Coulomb constant is approximately \(k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2\).
What is the force between two paint droplets when they are 1.5 diameters apart (center-to-center)? (Assume the charges on the two drops are separated by the distance between the two centers. With some calculus you can prove that this gives the correct force.)
\[ F = k \frac{q^2}{r^2} = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 \times \left(1.4 \times 10^{-11}\right)^2 \text{ C}^2 / \left(0.00009\right)^2 \text{ m}^2 = 2.17 \times 10^{-4} \text{ N} \]

How much charge should you put on each droplet to achieve the desired condition that the force between the droplets when they are 1.5 diameters apart is equal to the weight of a droplet? Give your answer in Coulombs.
Gravitational force = mg, Coulomb force = \(kq^2/r^2\) so
\[ mg = kq^2/r^2 \text{ so } q = \sqrt[2]{mgr^2/k} = \sqrt[2]{(1.13 \times 10^{-10} \text{ kg} \times 9.8 \text{ m/s}^2 \times 0.00009 \text{ m}^2 / 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2)} = 3.16 \times 10^{-14} \text{ C.} \]

You are in the market for a new flashlight and are considering several different configurations that are available. Your interests include the brightness of the light produced and how much run time you’ll get out of your rechargeable batteries. Below are a few configurations to consider. All of batteries shown are 1.5 Volt batteries. All the bulbs are identical (all have the same resistance). For each of these cases, the resistance in the wire and batteries is much smaller than the resistance of the bulb filament and so the resistance in the wire and batteries can be considered to be 0 for this problem.
The brightness of the light depends critically upon the voltage difference across the light bulb. In case A, the voltage difference is 1.5 V since the light bulb is simply connected across one battery. What is the voltage difference across the light bulb in the other cases? (if the voltage difference cannot be determined, enter N/A)

Case B? 3.0 V  
Case C? 1.5 V  
Case D? 6.0 V  
Case E? 3.0 V

The resistance of the light bulb filament is 10 ohms. What is the current flowing through the bulb in Case A?

\[ V = IR \text{ so } I = \frac{V}{R} = \frac{1.5\text{ V}}{10\text{ ohm}} = 0.15\text{ A} \]

How much power goes into heating the light bulb and producing light in Case A?

\[ P = IV = \frac{V^2}{R} = \frac{(1.5\text{ V})^2}{10\text{ ohm}} = 0.225\text{ W} \]

The more energy per second that goes into heating the filament, the hotter the filament and the brighter the light. Power is our measure for the energy per second. Let’s take a look at the differences that affect the amount of power that goes into heating the filament in Case A and Case D.

The number of electrons per second flowing through the bulb in Case D is ... the number flowing through the bulb in Case A:
The number of electrons going through per second is the current, and \( I=V/R \), so four times the voltage means four times the current.

The amount of electrostatic potential energy that each electron releases as it makes its way through the wire and the bulb back to the other end of the battery in Case D is the amount of energy that an electron releases in Case A:

The voltage is by definition the amount of EPE that each electron releases.

4. You are interested in outfitting your dining room with a new light fixture. Below are three possibilities you are considering. Case #1 just has a single bulb. Case #2 and Case #3 have three bulbs each, but are wired up differently.

The wall outlet provides a voltage difference of 120 Volts across the prongs on the plug. The resistance of each bulb filament is 240 ohms. Considering first, fixture #1 and fixture #2:
How much current flows through the circuit in Case #1?
I=V/R=120V/240ohm=0.5A

How much current flows through the circuit in Case #2?
The current is the same through all the bulbs, and they all have the same resistance, so the voltage across each one is 1/3 the total voltage, 120/3=40V. So the current through each one is I=V/R=40V/240ohm=0.17 A

How much electrical power is converted to heating the filament and producing light in Case #1?
P=IV=V^2/R=120^2 V^2 / 240 ohm = 60 W

How much electrical power is converted to heating the filaments and producing light in Case #2?
P=IV=0.17 A * 120 V = 20 W

Which of the following statements are true and which are false?
True   False   The current flow in the wire segment from the plug to Point A is larger than the current flow in the wire segment from Point D to the plug.
True   False   The voltage difference between A and D is 120 Volts
True   False   The bulb between A and B is the brightest of the three bulbs in Case #2.
True   False   The voltage difference between A and B is 120 Volts

Now consider Case #3. Which of the following statements are true and which are false?
True   False   The bulb connected between G and H will not light up.
True   False   The voltage difference between F and I is 120 V.
True   False   All three bulbs will light with equal brightness.
True   False   The bulb connected between E and J will be dimmer than the bulb in Case #1
True   False   The amount of electrical power converted to light in Case #3 is three times larger than in Case #1.
True  False  The current flow in the wire segment from E to J will be the same as the current flow in the wire segment from J to the plug.

Considering all three Cases.
Which of these light fixtures would provide the most lighting?
Case #3
For each bulb, $P = \frac{V^2}{R} = \frac{120^2}{240}$ Ohms = 60W, so the total power is $3 \times 60W = 180$ W, the most of the three configurations.

Which of these light fixtures would provide the least lighting?
Case #2
As we calculated above, it consumes the least power.