Name: JED'S COPY

A Test of Attraction

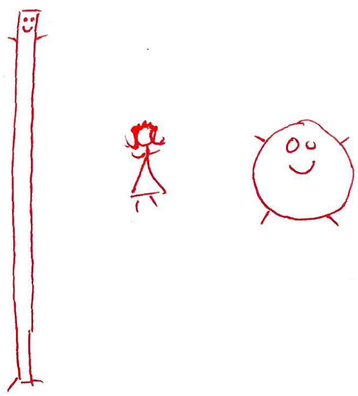
(and repulsion)

Please answer the following questions in the space provided. If you run out of room to show work in the space provided, please make a note and continue work on the back. Show *and explain* your work for any chance at partial credit!

Useful Constants
$g = 9.8\,\mathrm{m/s^2}$
$\epsilon_0 = 8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$
$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\mathrm{Nm^2/C^2}$

Prefix	10^n
k	10^3
c	10^{-2}
m	10^{-3}
µ	10^{-6}
n	10^{-9}
p	10^{-12}

(3) 1. Neutral Nancy has a decision to make. To her left she has Slim, a dashing stick of a man who is incredibly tall and incredibly thin. To her right, she has Bubba, a handsome bowling-ball of a man who is rounded like a beachball. Assume that both men have an equal amount of positive attributes (charge) and are standing the same distance away from Nancy (which is much shorter distance than Slim's height). As always, Nancy lets physics govern her heart. Which man will she be more attracted to? Explain your reasoning for full points.



Bubba looks like a point charge $\rightarrow \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$

Slim looks like a line charge $\rightarrow \frac{1}{4\pi\epsilon_0}\frac{2(Q/L)}{r}$

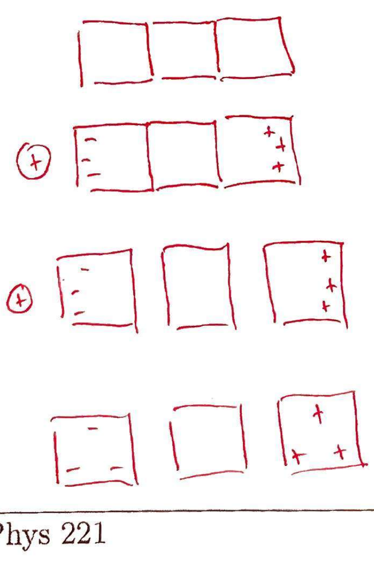
It is tempting to say Slim since his attractive force drops off as $\frac{1}{r}$ instead of Bubba's $\frac{1}{r^2}$. However, the charge on Slim is spread out over a much larger area, moving much of the charge far away. So Bubba will look more attractive to Nancy.

(4) 2. Three pieces of chocolate are wrapped with conducting foil and laid out in a horizontal line. Initially everything is neutral and the pieces of chocolate are not touching. The following sequence of events then takes place:

1. The chocolates are brought into contact with one another.
2. A positively charged rod is brought near the leftmost chocolate.
3. The chocolates are separated from one another.
4. The charged rod is removed.

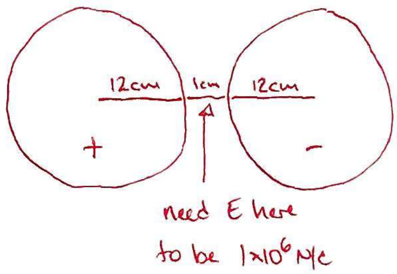
Determine if the final net charge on each chocolate in positive, neutral, or negative and explain yourself.

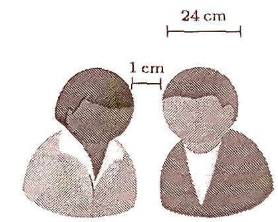
Final: left is negative
middle is neutral
right is positive



Bringing the charged rod near polarizes the conductor, separating the charge. By separating the conductors w/ the rod still near, this charge separation is "locked in".

(4) 3. Some couples are always looking for the spark in a relationship. To get a spark to jump across a gap of air, the electric field in the air must equal 1×10^6 N/C. Say one lovely couple with heads 24 cm in diameter are leaning in close for a kiss, such that only 1 cm of air separates them. Assuming equal and opposite charges on their two heads, what is the magnitude of charge needed to cause a spark to leap from one individual to the other?





outside of charged sphere

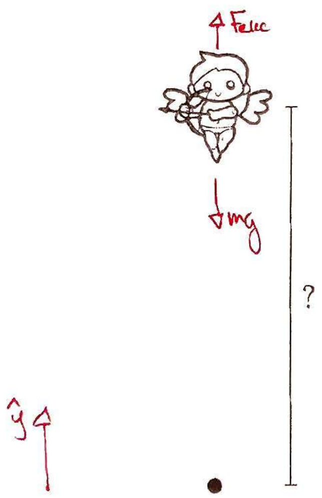
$$\Rightarrow E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

both will contribute to E field so 2x

$$E_{needed} = 2\left(\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\right) \Rightarrow q = \frac{4\pi\varepsilon_0 r^2 E_{needed}}{2} = \frac{4\pi(8.85\times10^{-12})(12.5\times10^{-2})^2(1\times10^6)}{2}$$

$= 868.8$ nC

(4) 4. A little known fact is that Cupid "flies" by hovering directly over charged arrows that he's dropped. A very positive and optimistic cherub, Cupid's wings maintain a positive charge of 10 mC. If each of Cupid's dropped arrows has a charge of 5 mC and Cupid has a mass of 15 kg, how high above the arrow (and ground) will he hover?



Will approximate as point charges

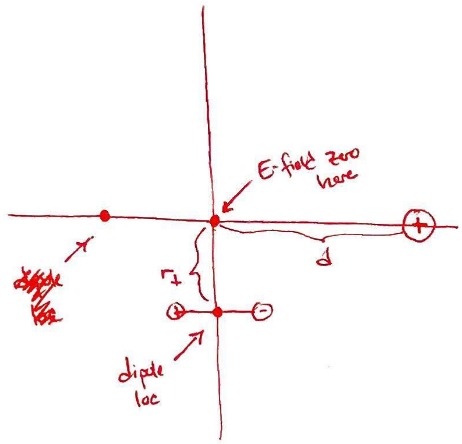
$$\Rightarrow F_{elec} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{y}$$ ← upward since both positive charges

$\Rightarrow F_{elec} = mg$ for $F_{net} = 0$ (hover)

$$\frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2} = mg$$

$$\sqrt{\frac{q_1 q_2}{4\pi\varepsilon_0 mg}} = r = \sqrt{\frac{(10\times10^{-3})(5\times10^{-3})}{4\pi(8.85\times10^{-12})(15)(9.81)}} = 55.27 \text{ meters!}$$

(4) 5. A very unromantic dipole sits centered at the position $\langle 0, -3, 0 \rangle$ cm. A positive charge of 10 nC is located at the point $\langle 10, 0, 0 \rangle$ cm. What dipole moment is necessary so that the electric field at the origin is zero? The dipole can have any orientation you need, and give your answer in vector form.



If my dipole moment pointed up or down, it would never cancel w/ the $-\hat{x}$ E field from the positive charge. So it needs to be horizontal and pointing in the negative dir

because the origin would then be $\perp$ and E field points opposite $\vec{p}$ on $\perp$

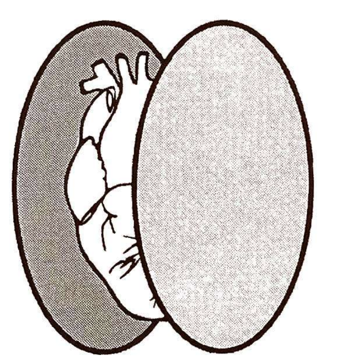
$$E_{dip} = E_{pcharge}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{p}{r_\perp^3} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{d^2}$$

$$|p| = \frac{Q r_\perp^3}{d^2} = \frac{(10\times10^{-9})(3\times10^{-2})^3}{(10\times10^{-2})^2} = 2.7\times10^{-11}\ \mathrm{Cm}$$

$$\Rightarrow \vec{p} = \langle -2.7\times10^{-11}, 0, 0 \rangle\ \mathrm{Cm}$$

(4) 6. Larry's heart skipped a few beats the first time he looked at Sue. Nothing has changed in the years since, and these days Larry is happily married and utilizes a pacemaker. Suppose that the pacemaker is comprised of two round disks 10 cm in diameter. The disks have equal and opposite charges and are place on either side of Larry's heart. What charge is needed on the plates to supply the 1000 N/C electric field that Larry's heart requires to beat steadily?



Assuming the disk are large compared to Larry's heart (little dicey here), then we know

$$E_{disk} \approx \frac{Q/A}{2\varepsilon_0}$$

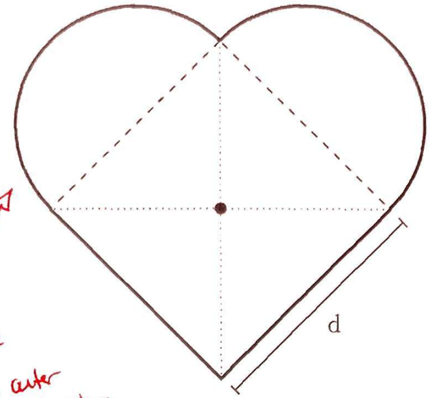
Here we have two whose effects add:

$$E_{middle} = \frac{Q/A}{\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

So we need $\varepsilon_0 E A = Q = (8.85\times10^{-12})(1000)\left(\pi\left(\frac{10\times10^{-2}}{2}\right)^2\right) = \cancel{0.278\ \mathrm{nC}}$

~ 69.5 pC

7. The heart shape below is charged uniformly with positive charge.



I meant for this to just have the charge on the outer perimeter

(2) (a) Based on simple geometry and symmetry arguments, determine what direction the electric field should be pointing at the given center point. Explain your reasoning!

The heart is left/right symmetric, so I'd expect the x component of the E-field to be 0. Looking up or down, charge below the midpoint is much closer to the midpoint than charge above, so I'd expect it to dominate. Thus I'd expect an upwards pointing E-field.

(bonus)) (b) Explain in words how you might go about breaking this problem into managable chunks and how you'd approach the different pieces. You technically know everything you'd need to solve this in its entirety, but it would be long.

I'd break it into 4 chunks: two straight line charge segments and two curved segments. For the straight segments I could just use our E-field at the center of a line charge equation w/ the proper lengths and distances. For the curved portions I'd have to work through the 4 step process to get the E-field at the center.

If you haven't grabbed one yet, there are chocolates up front so grab one on your way out! Have a lovely rest of your Valentines day!!