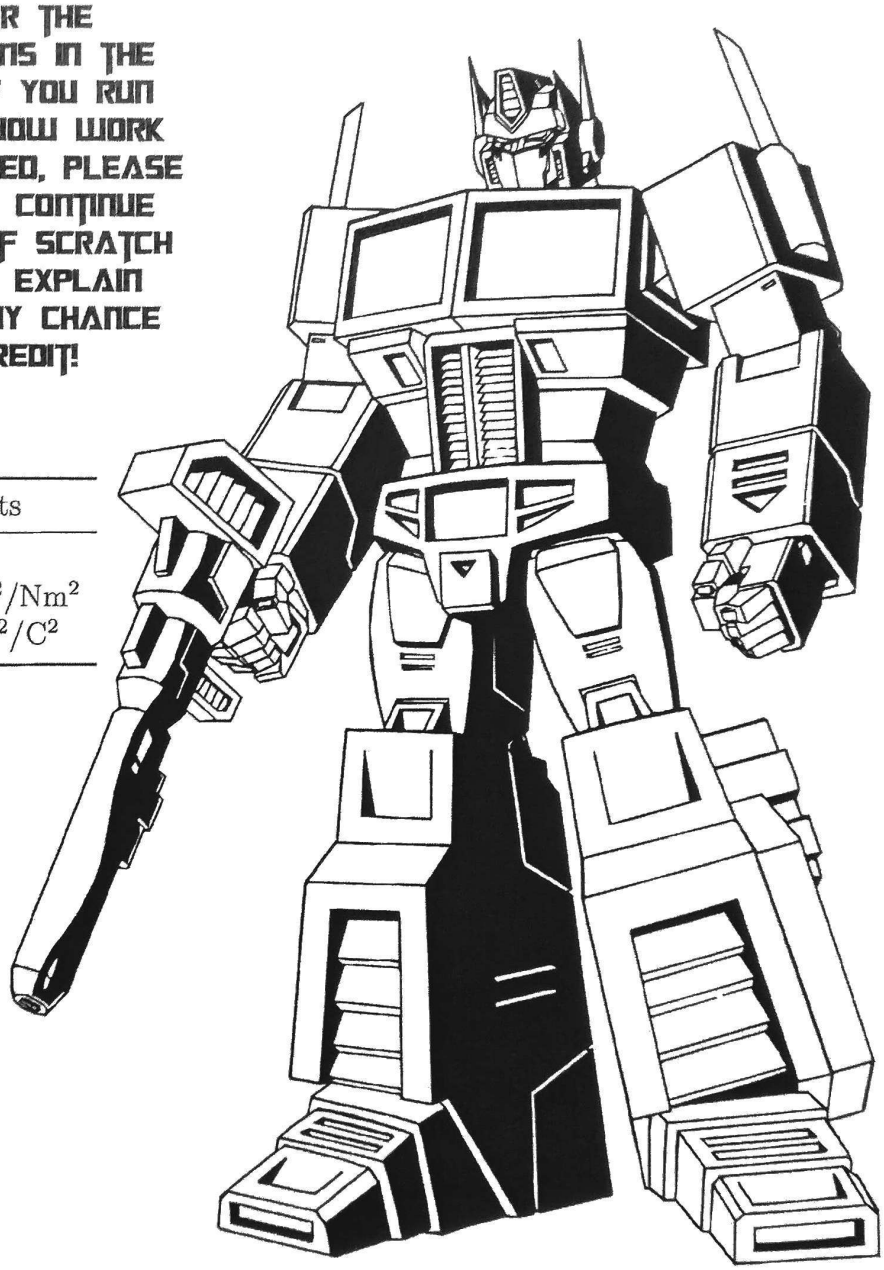
Phys 222 February 22, 2019

Name: JED'S COPY

TEST 1

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 A PIECE OF SCRATCH PAPER. 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}

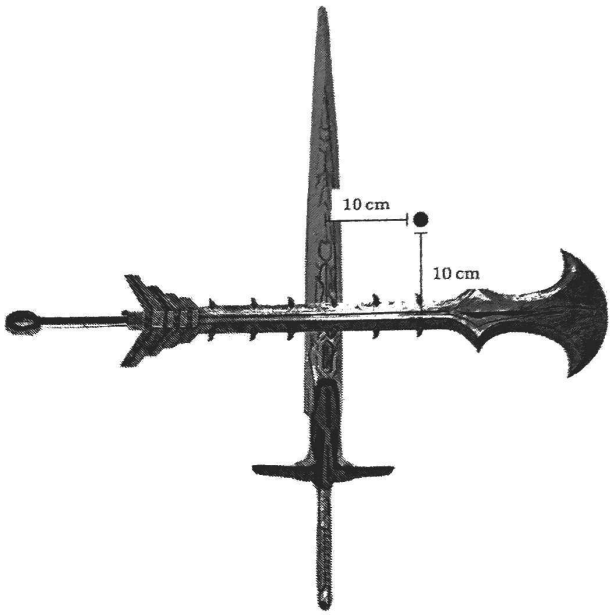
Good luck!

(5) 1. In an epic battle, Optimus Prime and Megatron are fighting with their respective swords. Interestingly, both swords have acquired a large amount of charge over the course of the fight. Optimus' sword (up and down) has a total charge of 500 mC and Megatron's sword (left and right) a total charge of −300 mC. Approximate both swords as 10 m long line charges. What is the electric field 10 cm from the intersection of the crossed swords (point is marked in image)? Be sure to justify any approximations you might have made.

$$\vec{E}_{optimus} = \frac{1}{4\pi\varepsilon_0}\frac{2(Q/L)}{r}\hat{x}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2(500\times10^{-3}/10)}{10\times10^{-2}}\langle 1,0,0\rangle$$

$$= \langle 9\times10^{9}, 0, 0\rangle \text{ N/C}$$



$$E_{megatron} = \frac{1}{4\pi\varepsilon_0}\frac{2(Q/L)}{r}\hat{y}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2(-300\times10^{-3}/10)}{10\times10^{-2}}\langle 0,1,0\rangle$$

$$= \langle 0, -5.4\times10^{9}, 0\rangle \text{ N/C}$$

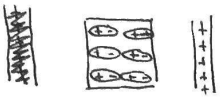
So $\vec{E}_{net} = \vec{E}_{opt} + \vec{E}_{mega} = \langle 9\times10^{9}, -5.4\times10^{9}, 0\rangle = \langle 9, -5.4, 0\rangle$ GN/C

Here I made the assumption that since 10 cm ≪ 10 m, I was safe to use the approximate formula for the electric field far from the ends

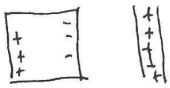
(4) 2. In truth, a super charged sword would be a bit cumbersome, as it would attract all sorts of neutral objects. Explain why both Optimus and Megatron's swords would both attract neutral objects. Make sure you address both conductors and insulators.

Both charged swords would attempt to polarize nearby neutral objects, pulling opposite charges nearer and repeling similar charges.

In insulators the charges are not free to leave their atoms, so we just get induced dipoles created

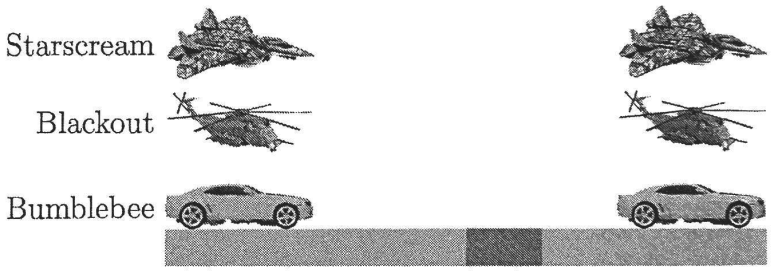


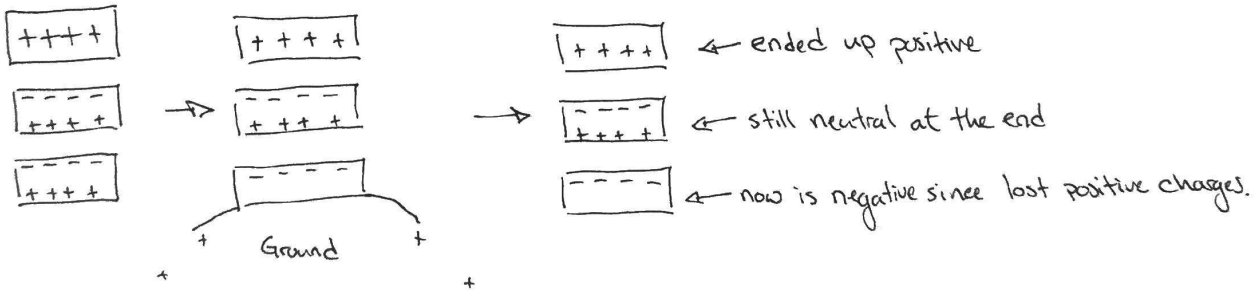
In conductors the charges in the metal would separate until the induced E-field would counteract the external field



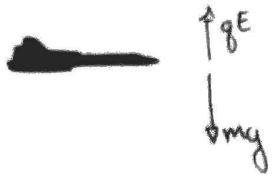
In both cases, more of the opposite charge end up closer to the charged sword. Since the E-field for line charges drops off as $\frac{1}{r}$, the attractive force will be stronger than the repulsive force, resulting in net attraction.

(4) 3. Bumblebee, Blackout, and Starscream are racing over an insulating material. Starscream is the topmost and is strongly positively charged. Both Blackout and Bumblebee are initially neutral and are not touching. As they race across the terrain, each above the other, Bumblebee crosses a short patch of conducting ground that grounds him for a moment before they move back onto insulating terrain. At the end, is the net charge on each positive, neutral, or negative? Explain in detail how you came to your conclusions.





(4) 4. Jetfire is an Autobot who converts into a Lockheed SR-71 airplane. Imagine that instead of flying by convential means though, he maintains his lift by positively charging both himself and the nearby ground. If Jetfire has a mass of 3000 kg and charges himself to 5 C, what surface charge density must he induce on the ground to hover motionless? You can imagine the ground to be a massive charged surface, so Jetfire is always flying much closer to it than the dimensions of the surface.



$$\Sigma F_{net} = 0 = qE - mg$$

$$\Rightarrow E = \frac{mg}{q}$$

$$\frac{\sigma}{2\varepsilon_0} = \frac{mg}{q}$$

$$\sigma = \frac{2\varepsilon_0 mg}{q}$$

$$= \frac{2(8.85\times10^{-12})(3000)(9.81)}{5}$$

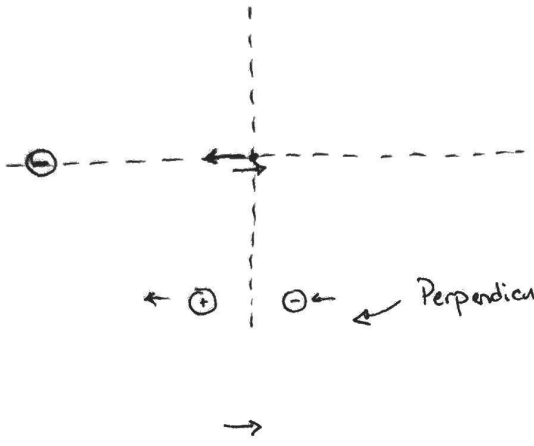
$$= 1.042\times10^{-7}\ C/m^2$$

$$= 104.2\ nC/m^2$$

(4) 5. Being a machine, it can aid Optimus Prime in combat if he is able to discern and calculate the electric fields throughout space. To do so, he runs a *very* advanced version of Glowscript to calculate the net electric field due to a large list of charges. A glancing blow seems to have caused a portion of his code to vanish. Fill in any needed lines of code to ensure Optimus can calculate the electric field at the observation point he desires due to his large list of charged objects.

```
oofpez = 9E9

# Optimus generates his list of charged objects and returns it to you
# as list_of_charges. Note that each object in the list has some
# charge attached to it called q. An example charge might look like:
# sphere(pos=vec(0,0,0), radius=1, q=1E-6)

obsloc = vec(2,2,2) # where Optimus wants to know the Enet

Enet= vec(0,0,0)

for charge in list_of_charges: # Looping through the list of charges
        r = obsloc - charge.pos
    dE = oofpez * charge.q * r.hat / r.mag**2
    Enet = Enet + dE

print(Enet)
```

(6) 6. The Decepticon Barricade is located at the point (-20,0,0) and has a negative charge of $-20\,\text{mC}$. The Autobot twins Skids and Mudflap have equal and opposite charges of $15\,\text{mC}$ and $-15\,\text{mC}$, respectively. What is one valid location for both Mudflap and Skids that would result in the electric field at the origin being 0? You have lots of options here. Any combination of locations for Skids and Mudflap will be fine, so long as the electric field at the origin is zero.



$E_{dipole} = \frac{1}{4\pi\varepsilon_0}\frac{qs}{r^3}$

let's make $s = 2$ so we can center them a distance of 1 on either side of the y-axis.

So then to solve for the distance away (r). The E-fields need to cancel, so

$$E_{point} = E_{dipole}$$

$$\frac{1}{4\pi\varepsilon_0}\frac{q_s}{(20)^2} = \frac{1}{4\pi\varepsilon_0}\frac{q(2)}{y^3}$$

$$\Rightarrow y^3 = \frac{(15\times10^{-3}\,C)(2\,m)(20\,m)^2}{(20\times10^{-3}\,C)} = 600\,m^3$$

$$y = 8.43$$

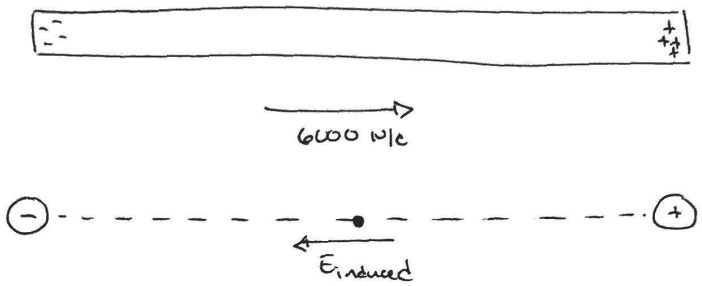
So we could place them at

$$\text{Skids} = \langle -1, -8.43, 0\rangle\,m$$

$$\text{Mudflap} = \langle 1, -8.43, 0\rangle\,m$$

Probably marginal that $r \gg s$ here though.

! (bonus)) 7. The Autobot Jolt has long electric whips that he utilizes as weapons. Suppose the whip is made of a conducting material and is 5 m long. If Jolt applies a constant electric field of 6000 N/C over the length of the whip, estimate the amount of charge that builds up on the ends of the whip. like graphene HW



$$\frac{1}{2} E_{induced} = \frac{1}{4\pi\varepsilon_0} \frac{q_+}{2.5^2}$$

$$3000 \text{ N/C} = 9\times10^9 \frac{Q}{2.5^2}$$

$$\Rightarrow Q \approx 2.08\times10^{-6} \text{ C}$$

↑ and negative that on the other end.

You made it! Now go and have yourself a lovely, homework free weekend!
Autobots, roll out!