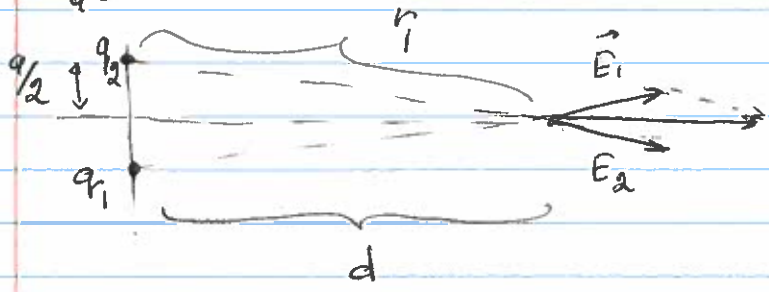
# Written assignment #3 solutions

Q3

a)




$\vec{E}_1 + \vec{E}_2$ — only x-component

$$E_{1x} = \frac{kq}{r_1^3} \cdot d =$$

$q_1 = q_2 = q$

I label them for convenience

$$= \frac{kq}{(d^2 + a^2/4)^{3/2}} \cdot d$$

$$E_{2\,charges} = \frac{2kq}{(d^2 + a^2/4)^{3/2}} \cdot d$$

$$E_0 = \frac{kq}{d^2}$$

b) $a = d/10$

$$E_{2\,charges} = \frac{2kq}{(d^2 + d^2/400)^{3/2}} \cdot d = \frac{2kq}{d^2\left(1 + \frac{1}{400}\right)^{3/2}} \approx 1.9925\, E_0$$

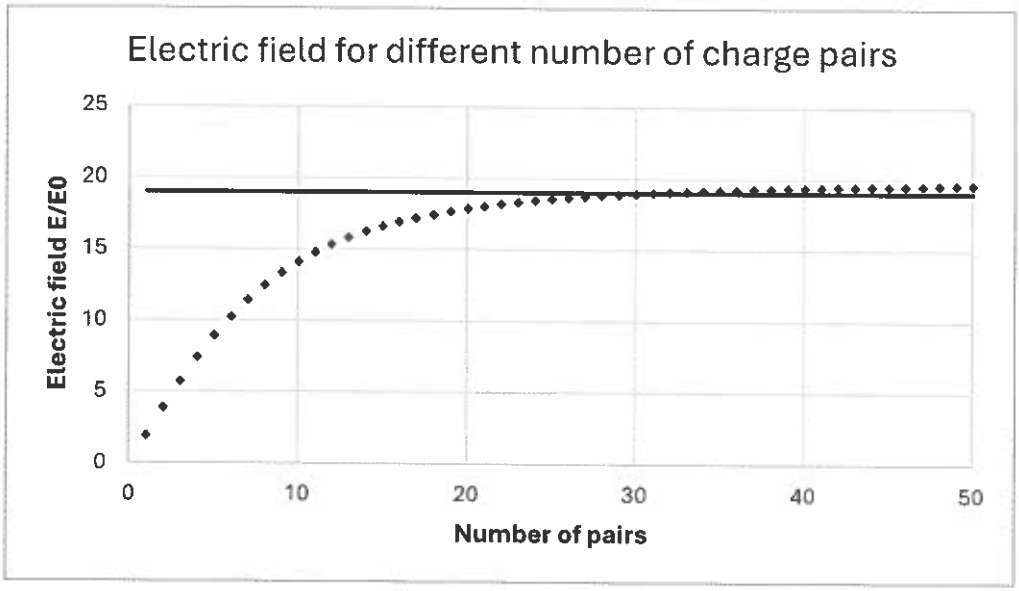
c) Each additional pair of charges adds similar contribution, with larger intercharge distance $1/2\,a \to 3/2\,a,\ 5/2\,a,\ 7/2\,a$, etc.

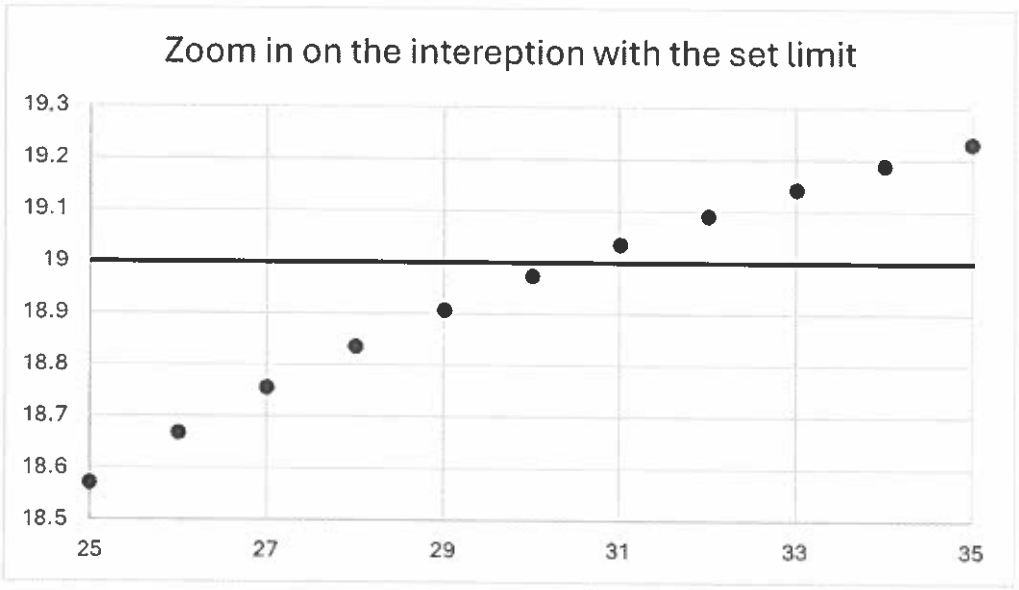
$$E_{4\,charges} = E_{2\,charges} + \frac{2kq}{d^2} \frac{1}{\left(1 + \frac{9}{400}\right)^{3/2}} \approx 3.927\, E_0$$

$$E_{6\,charges} = E_{4\,charges} + \frac{2kq}{d^2} \frac{1}{\left(1 + \frac{25}{400}\right)^{3/2}} \approx 5.753\, E_0$$

$$E_{8\,charges} = E_{6\,charges} + \frac{2kq}{d^2} \frac{1}{\left(1 + \frac{49}{400}\right)^{3/2}} \approx 7.435\, E_0$$

d) We need approximately **34** charge pairs (**62** charges) to ~~get within the 5~~ reach 95% of uniformly charged wire approximation.


Electric field for different number of charge pairs
Electric field E/E0
25
20
15
10
5
0
0
10
20
30
40
50
Number of pairs


Zoom in on the intereption with the set limit
19.3
19.2
19.1
19
18.9
18.8
18.7
18.6
18.5
25
27
29
31
33
35

Q2

Let's assume for simplicity that the center of the room is in origin.

Since in any case we know all the charges and their locations, we can calculate electric field they create at the center of the room

1D: $\vec{E} = E_x \vec{i}$

2D: $\vec{E} = E_x \vec{i} + E_y \vec{j}$

3D: $\vec{E} = E_x \vec{i} + E_y \vec{j} + E_z \vec{k}$

The field created by the play charge will be $\vec{E}_{play} = \frac{kq}{r^3} \vec{r}$

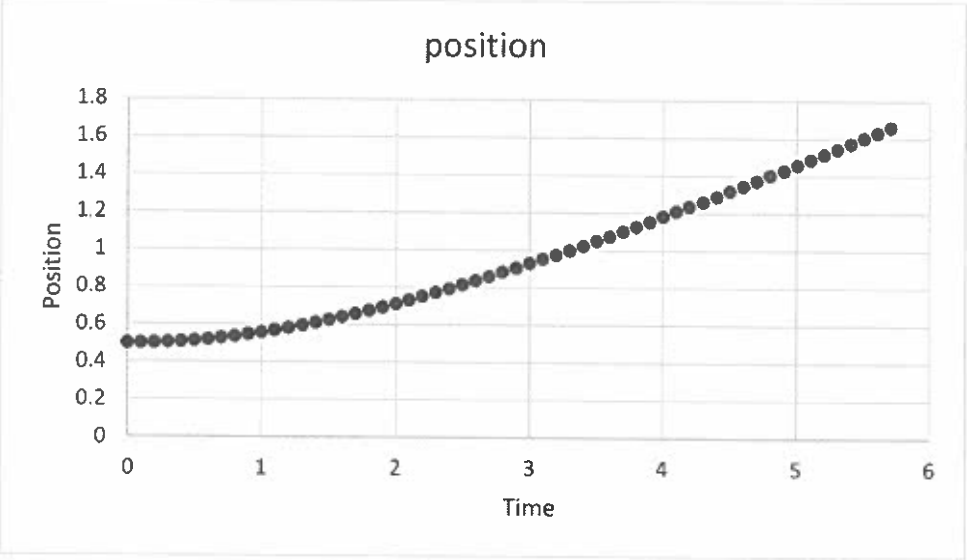
and we need to make sure that $\vec{E} + \vec{E}_{play} = 0$

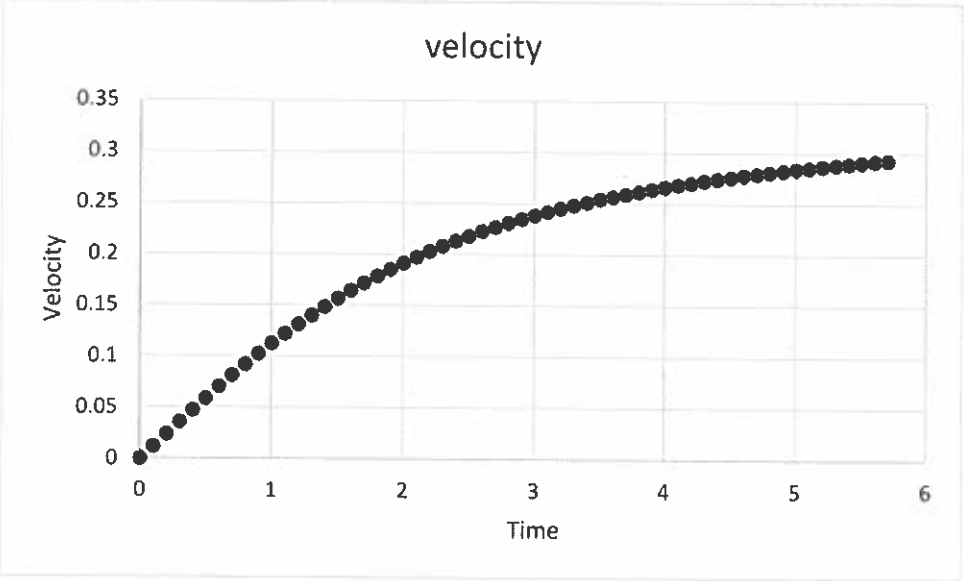
1D: $\frac{kq}{x^2} + E_x = 0$ Can always solve for either x for given q or either q for given x

but knowing "q" is cheaper, so 1D case can be solved for 5 coins.

2D and 3D: we need to independently match 2 or 3 components. The value of charge scales all components simultaneously, so it won't work. However, if we can control the charge location, we can make sure that each component of the e-field is compensated in both 2D or 3D case, and it will cost 10 coins.

Q2


position
Position
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
5
6
Time


velocity
Velocity
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
Time