

## Unit 20

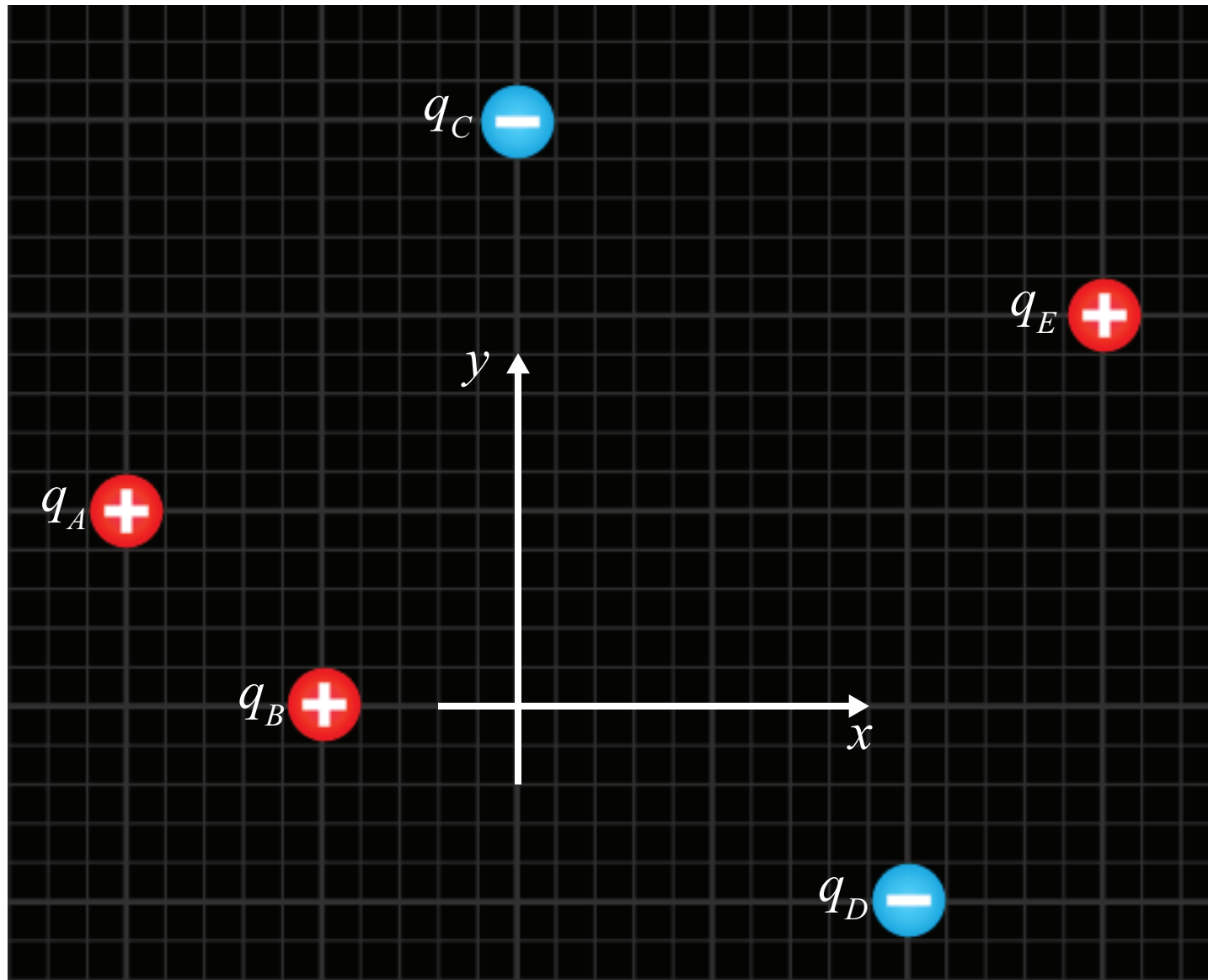
Just like last semester in Physics 211, our ultimate goal is to find the net force,  $\vec{F}^{net}$ , acting on an object  $\Rightarrow$  this will then allow us to find the change in momentum,  $\Delta\vec{p}$ , of the object (how the object changes its motion).

- $\vec{F}^{net} = \vec{F}^{grav} + \vec{F}_i^{norm} + \vec{F}_i^{tens} + \vec{F}_i^{fric} + \dots$
- (the  $i$  subscript is because there can be more than one normal force, etc.)

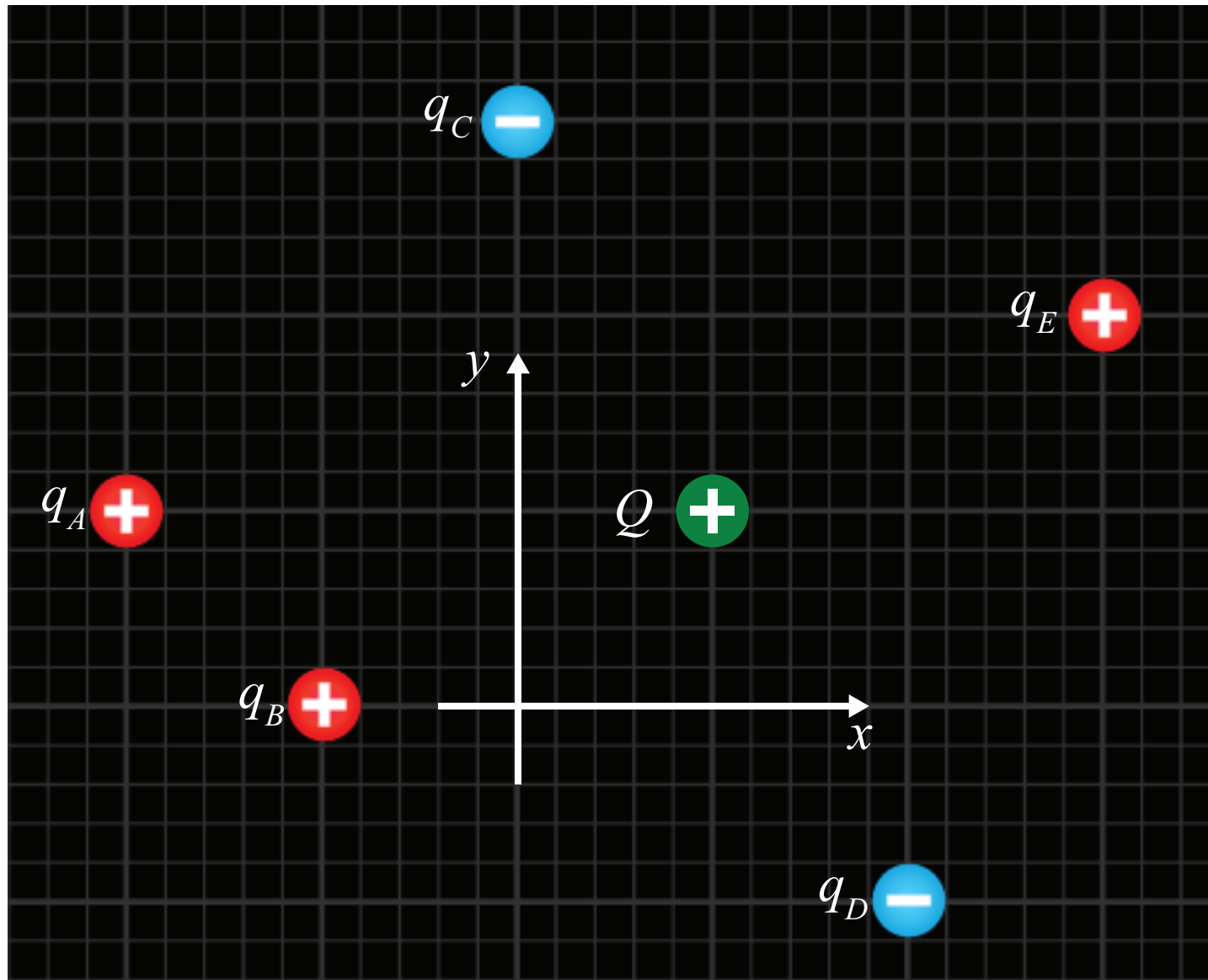
We hadn't included it before, but now one of the forces acting on the object could be the electric force,  $\vec{F}^{elec}$ .

- $\vec{F}^{net} = \vec{F}^{grav} + \vec{F}_i^{norm} + \vec{F}_i^{tens} + \vec{F}_i^{fric} + \vec{F}^{elec} + \dots$

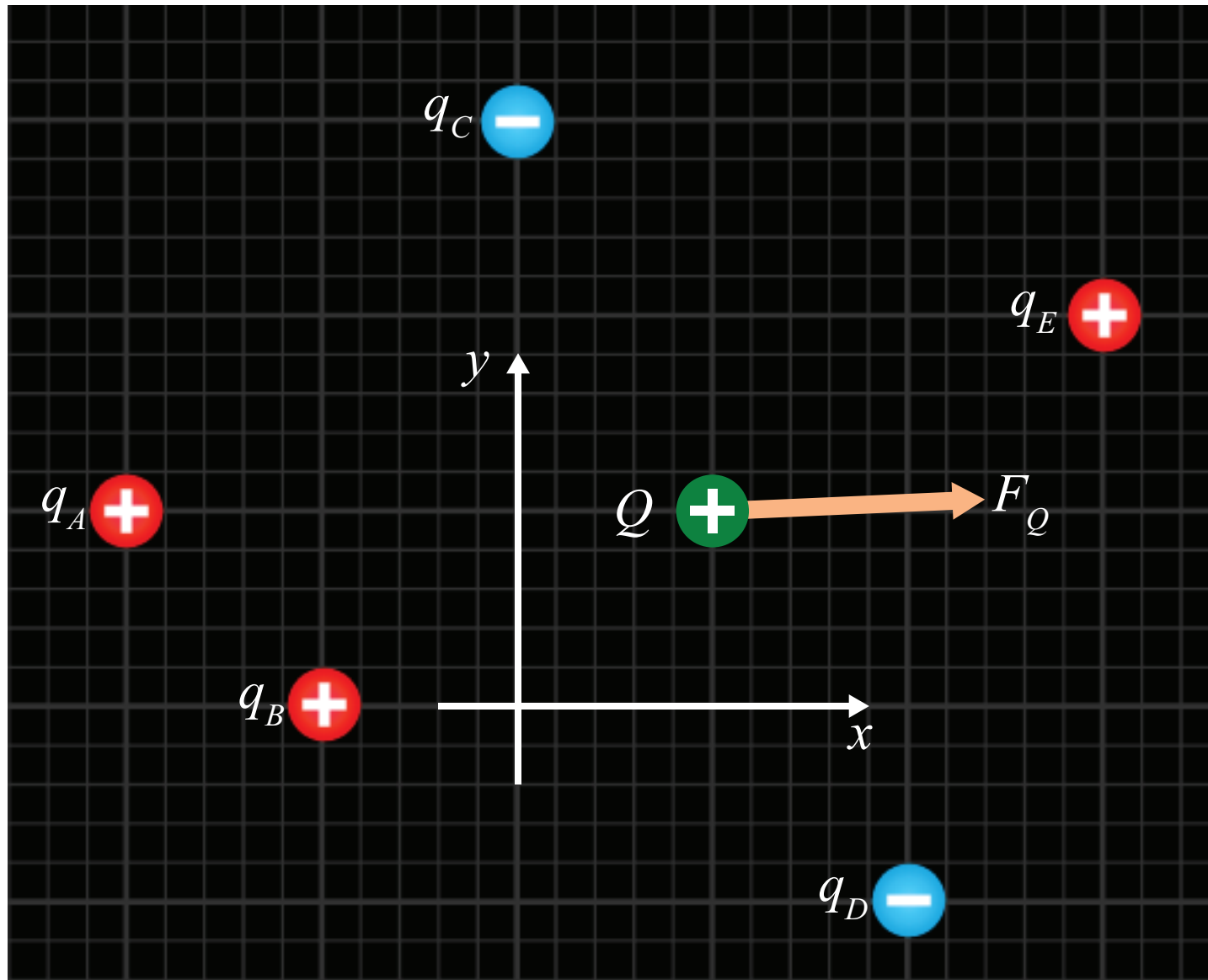
Let's do a quick review from Unit 19 on how we found the electric force,  $\vec{F}^{elec}$ .



Consider a situation where there are 5 point charges, each held in place so they can't move – we say they are fixed. (I just arbitrarily picked 5 – it can be 1, or 2, or 96, or 234 – as many or few as you want.)



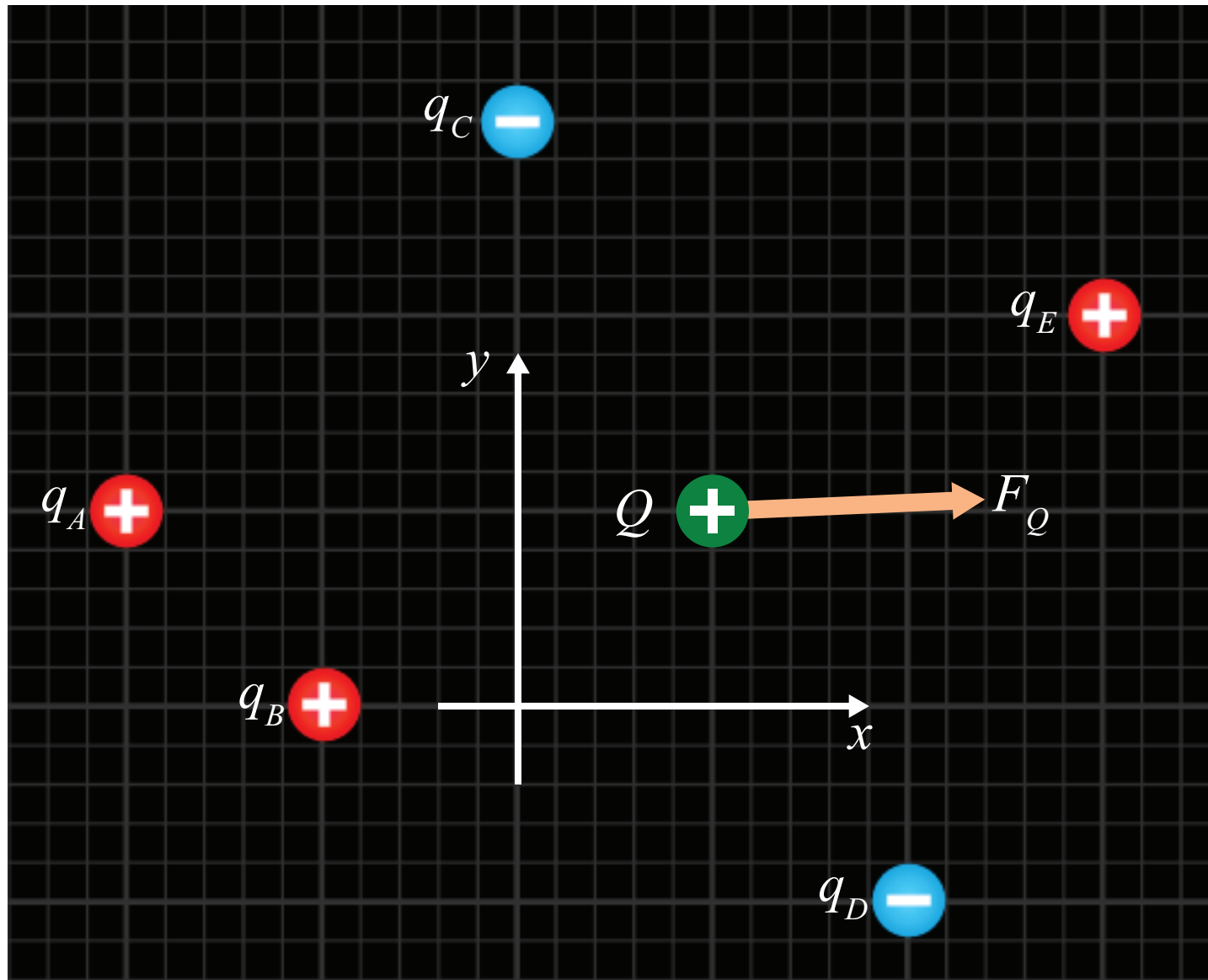
We want to find the total (net) electric force acting on a 6<sup>th</sup> charge, caused by the 5 fixed charges.



We could find it directly using Coulomb's Law (these are point charges).

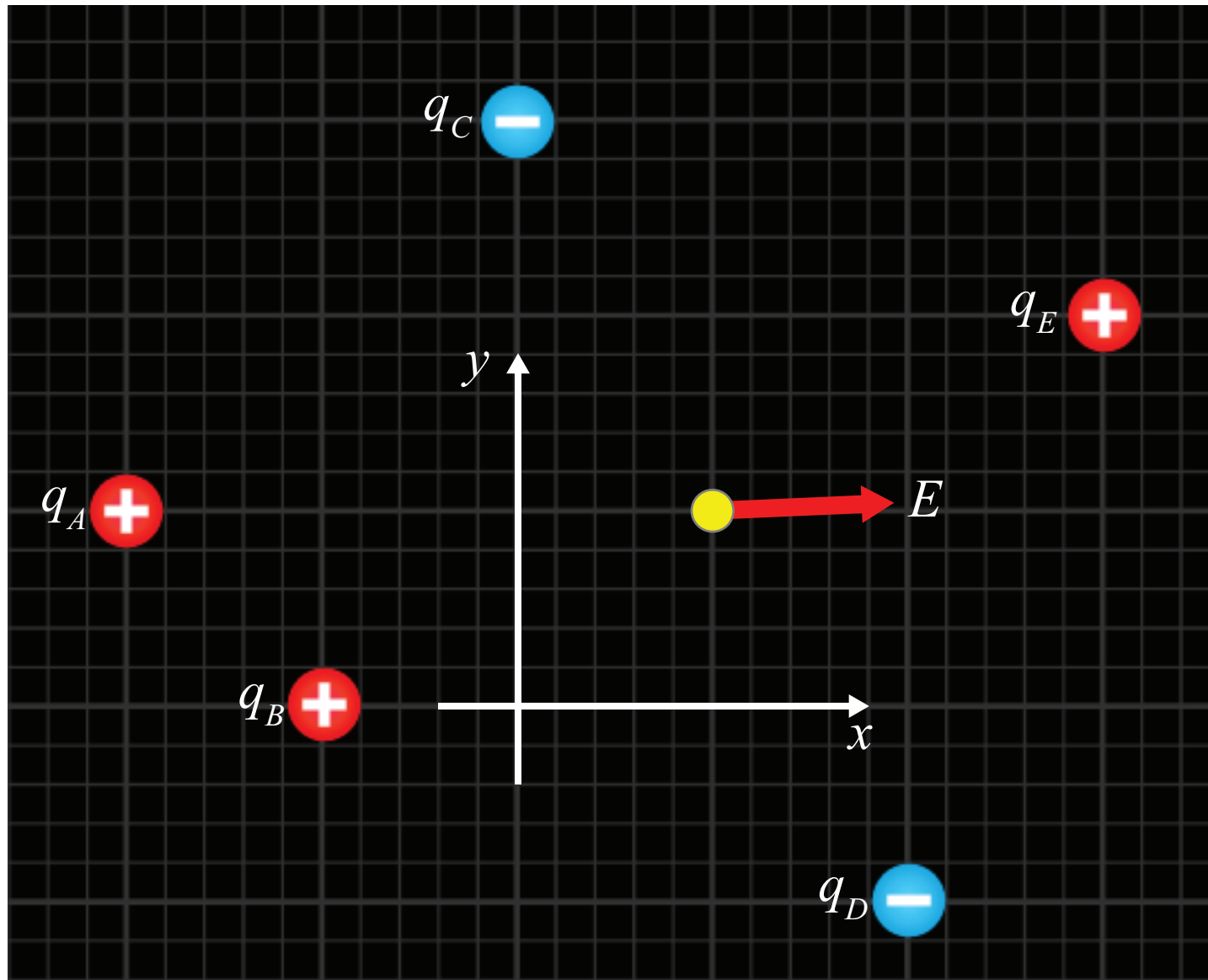
$$\vec{F}_Q^{elec} = \frac{kq_A Q}{r_A^2} \hat{r}_A + \frac{kq_B Q}{r_B^2} \hat{r}_B + \frac{kq_C Q}{r_C^2} \hat{r}_C + \frac{kq_D Q}{r_D^2} \hat{r}_D + \frac{kq_E Q}{r_E^2} \hat{r}_E.$$





Remember:  $\hat{r}_n = (1)\cos\theta_n \hat{x} + (1)\sin\theta_n \hat{y}$        $\theta_n = \text{angle w.r.t. } +x\text{-axis.}$

Here:  $\theta_A = 0^\circ$ ,  $\theta_B = 26.6^\circ$ ,  $\theta_C = -63.4^\circ$ ,  $\theta_D = 116.6^\circ$ ,  $\theta_E = -153.4^\circ$

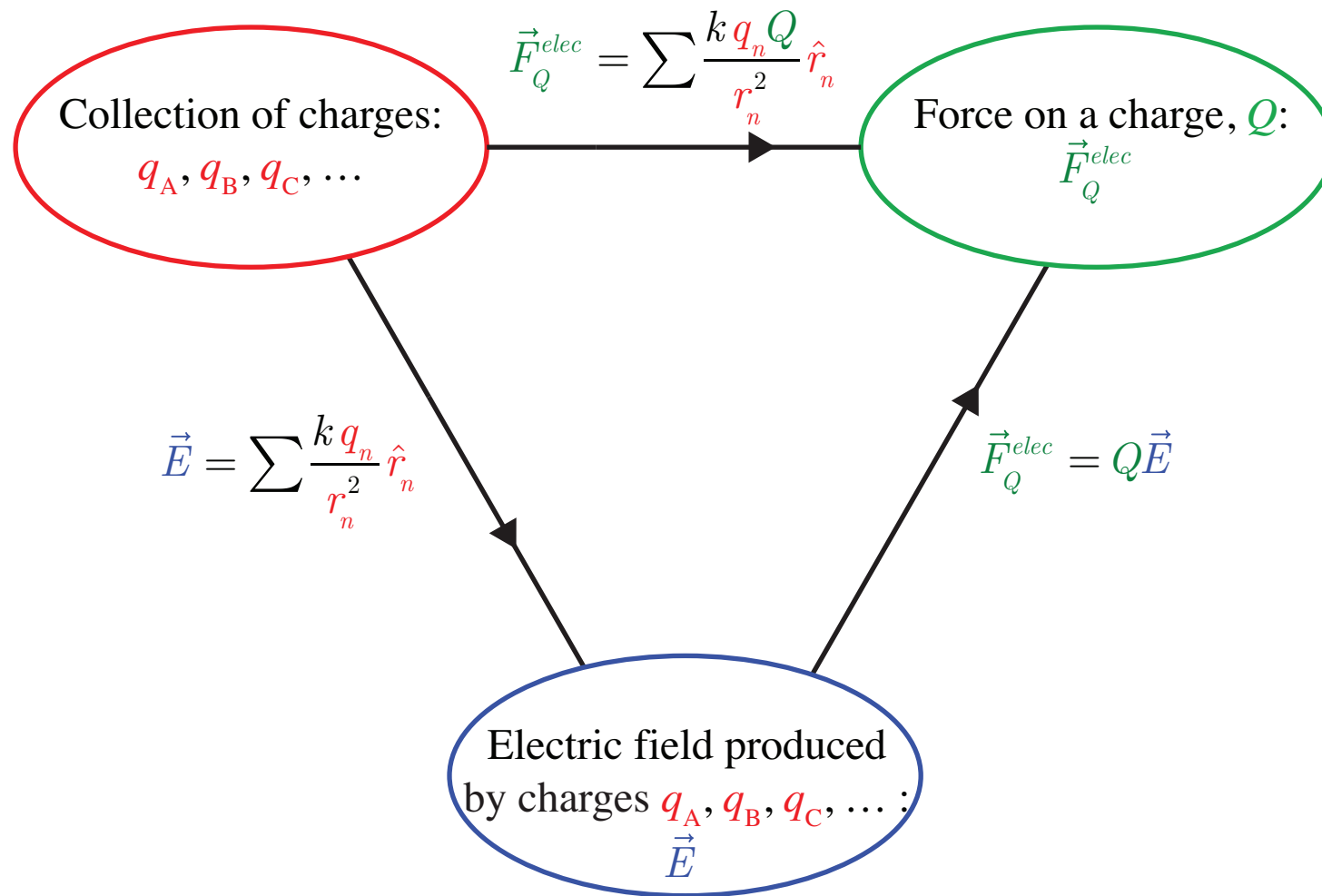


Alternatively, we could first find the electric field at that location.

$$\vec{E} = \frac{kq_A}{r_A^2} \hat{r}_A + \frac{kq_B}{r_B^2} \hat{r}_B + \frac{kq_C}{r_C^2} \hat{r}_C + \frac{kq_D}{r_D^2} \hat{r}_D + \frac{kq_E}{r_E^2} \hat{r}_E.$$

Then $\vec{F}_{\text{Q}}^{\text{elec}} = Q \vec{E}$
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Here are the two methods shown in a flowchart.



- For point charges  
 $\Rightarrow \vec{F}^{elec}$  (or  $\vec{E}$ ) is tedious to calculate.
- For charge distributions  
 $\Rightarrow \vec{F}^{elec}$  (or  $\vec{E}$ ) is often very difficult to calculate.

In this unit, we will develop a new way to calculate  $\vec{E}$

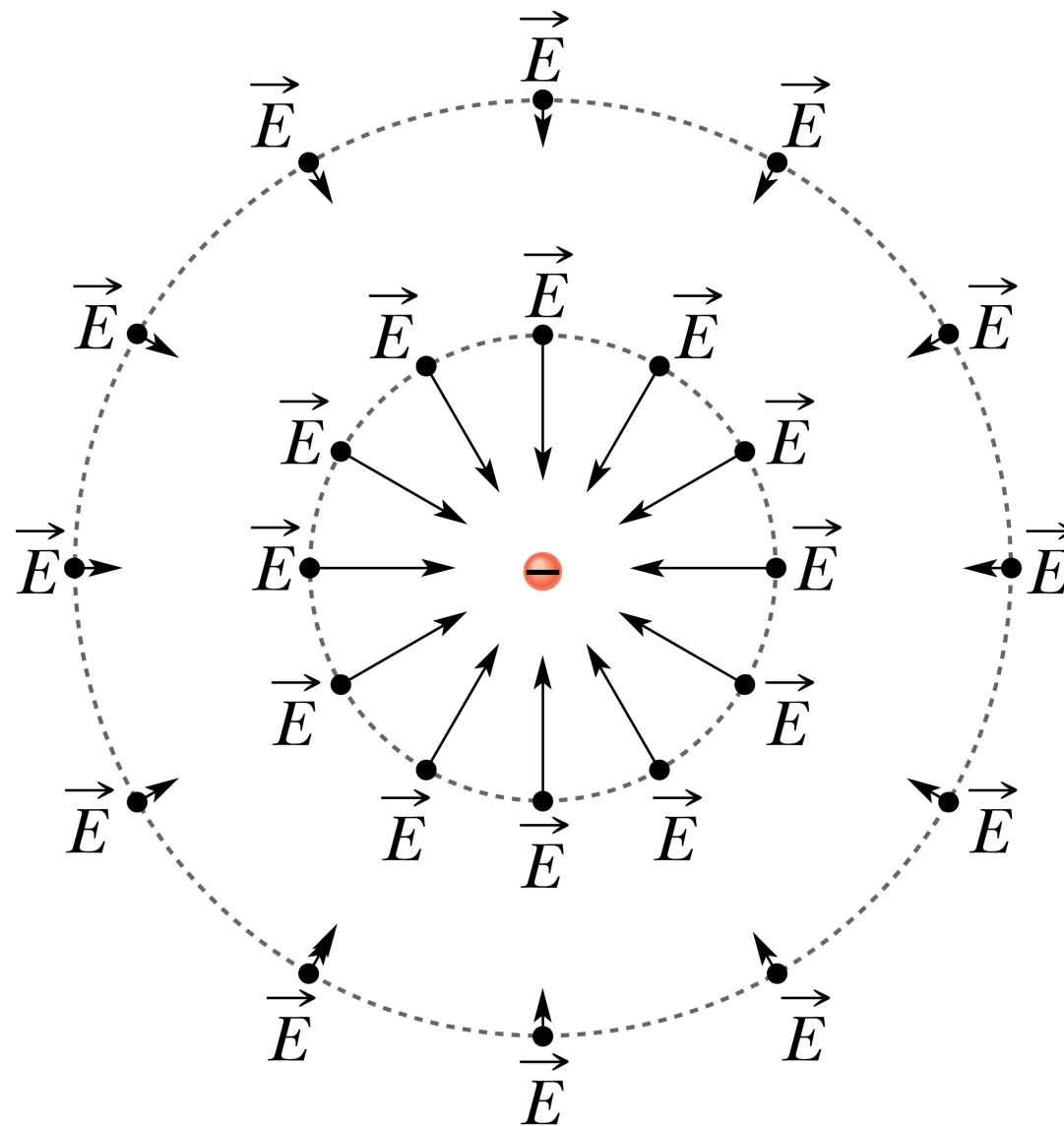
- For many problems  
 $\Rightarrow$  new way still often very difficult to find  $\vec{E}$ .
- For problems with uniform, symmetric charge distributions  
 $\Rightarrow$  new way very easy to find  $\vec{E}$ .

First, we need to introduce three new concepts:

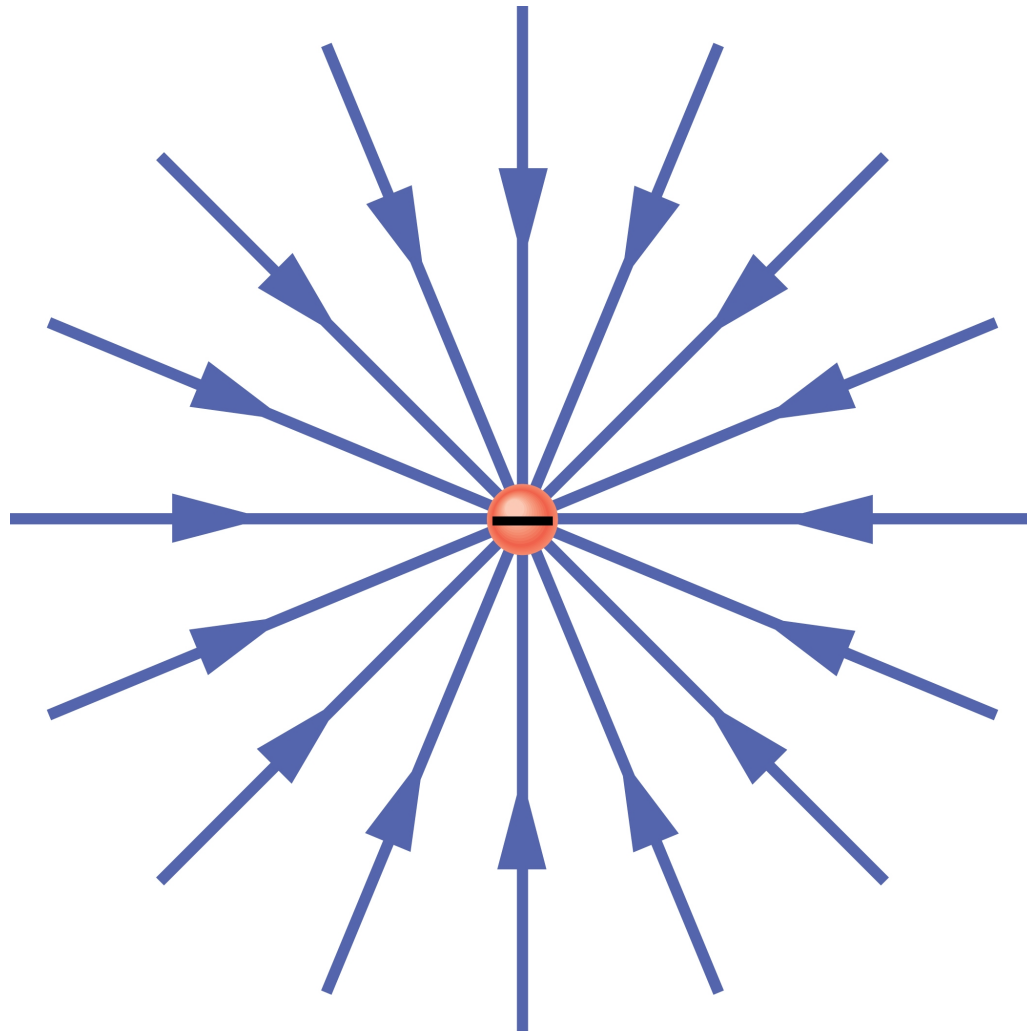
1) (Electric) field lines.

2) Area as a vector,  $\vec{A} = A\hat{n}$

3) (Electric) flux,  $\Phi^{elec}$

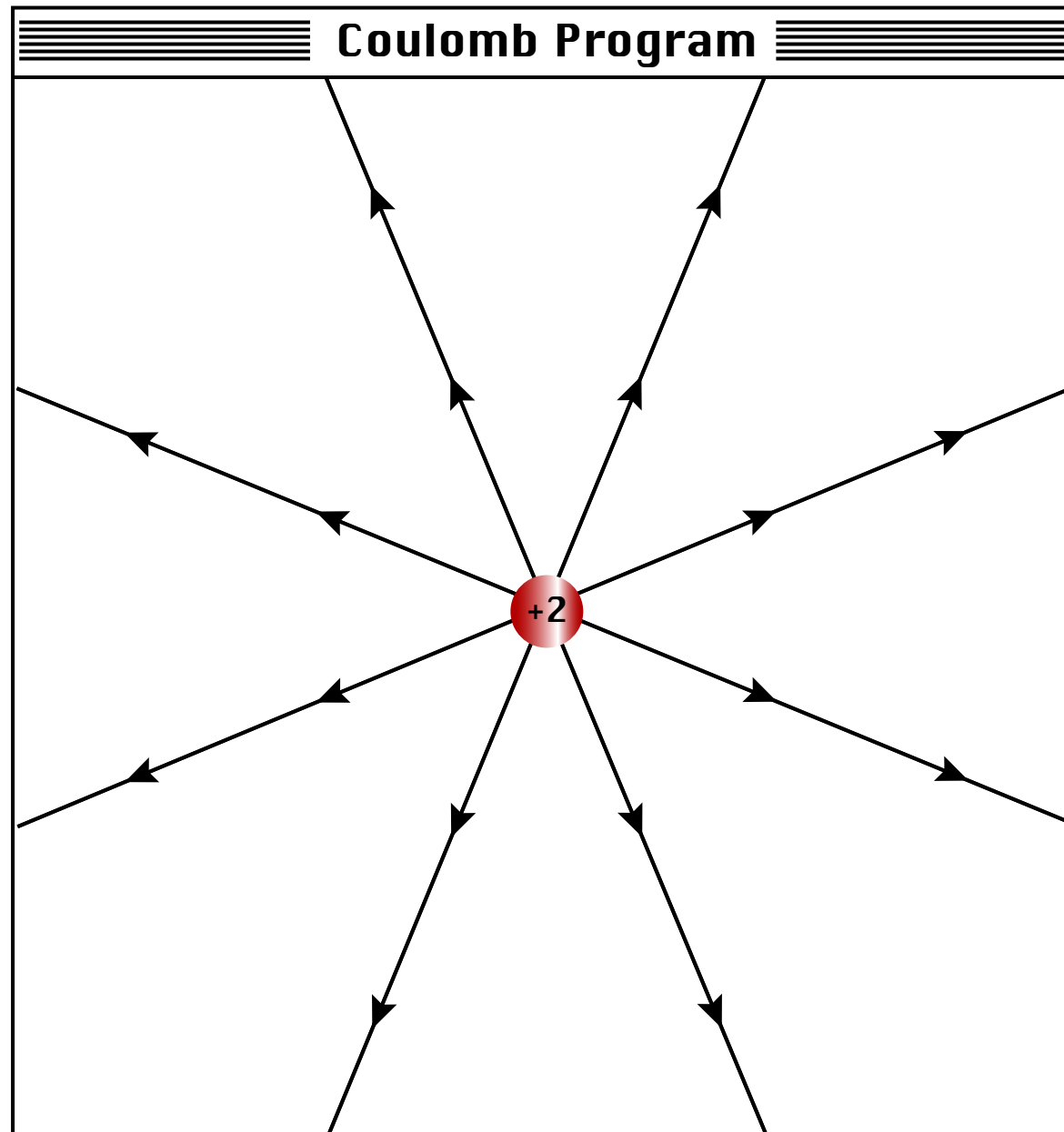


Electric field vectors



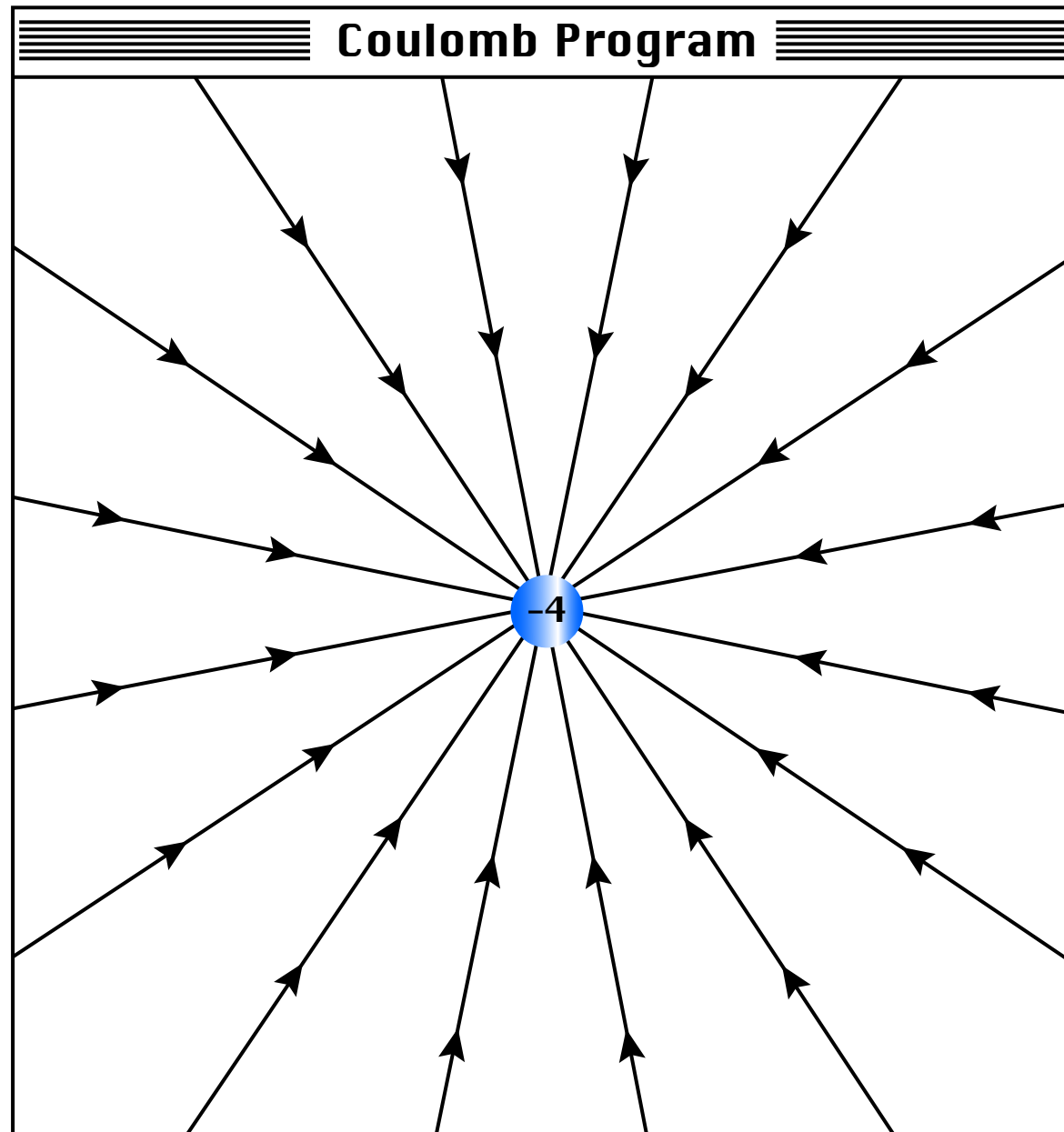
Electric field lines

Activity 20.2.1 a.

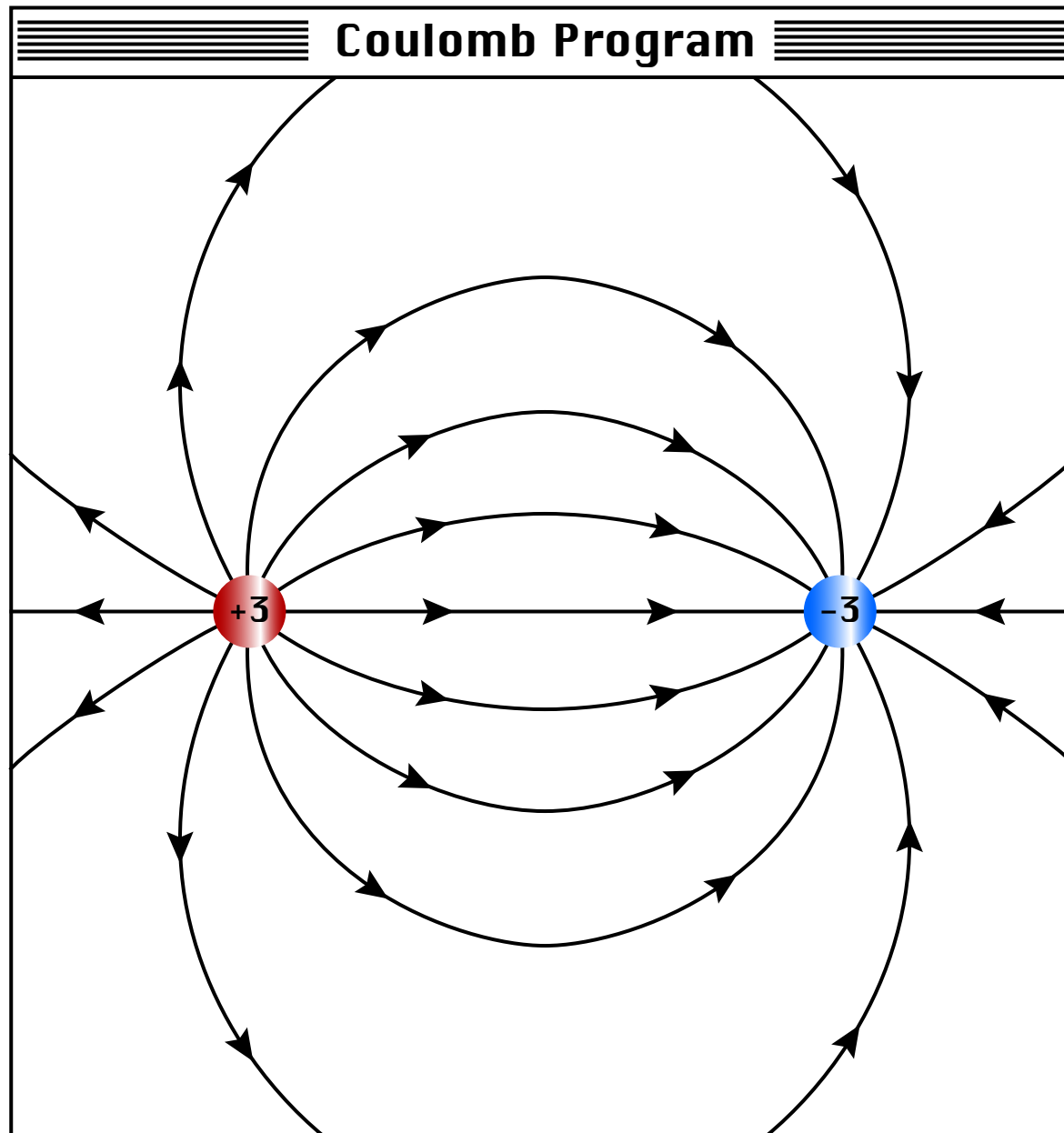




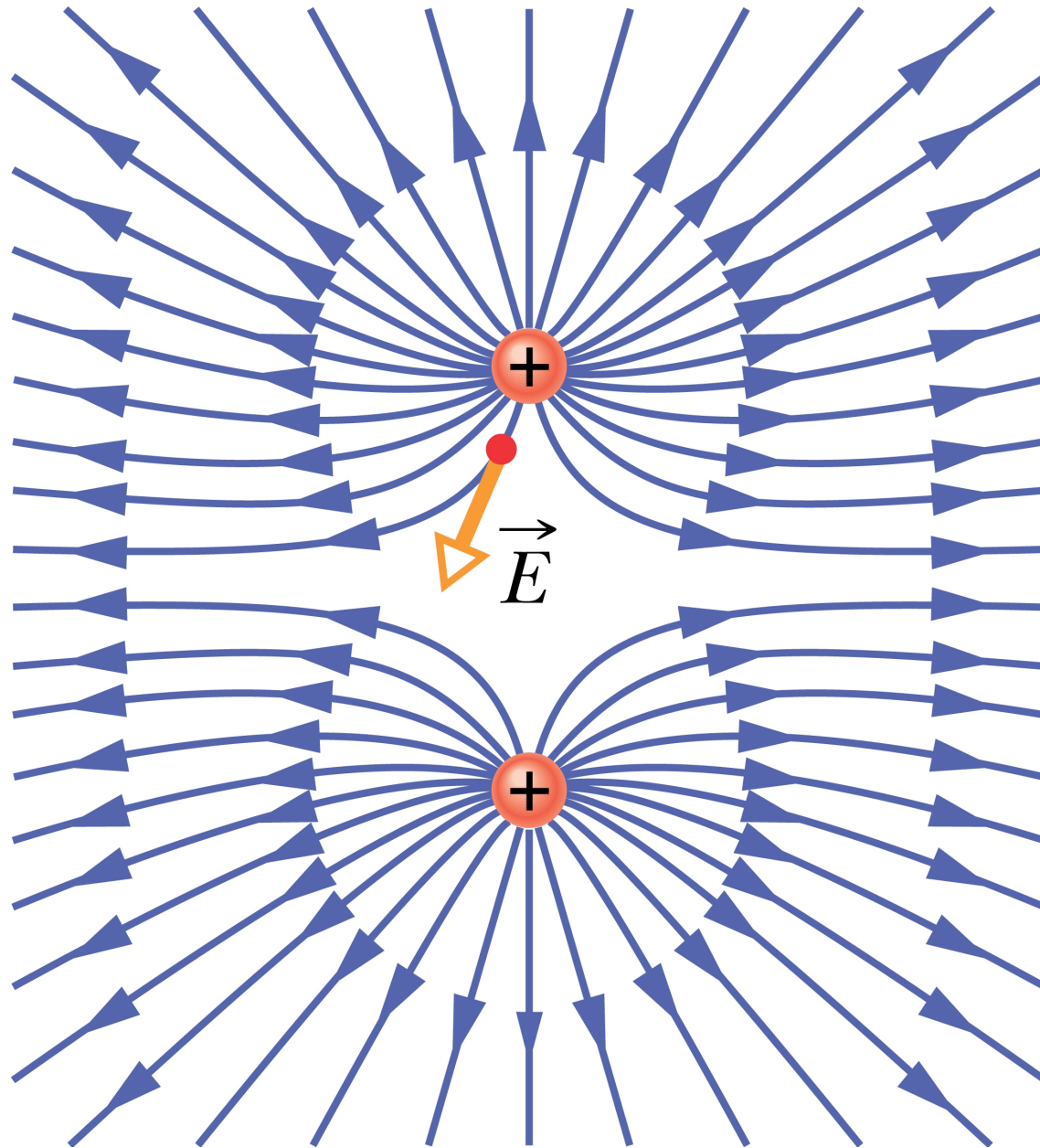
Activity 20.2.1 b.



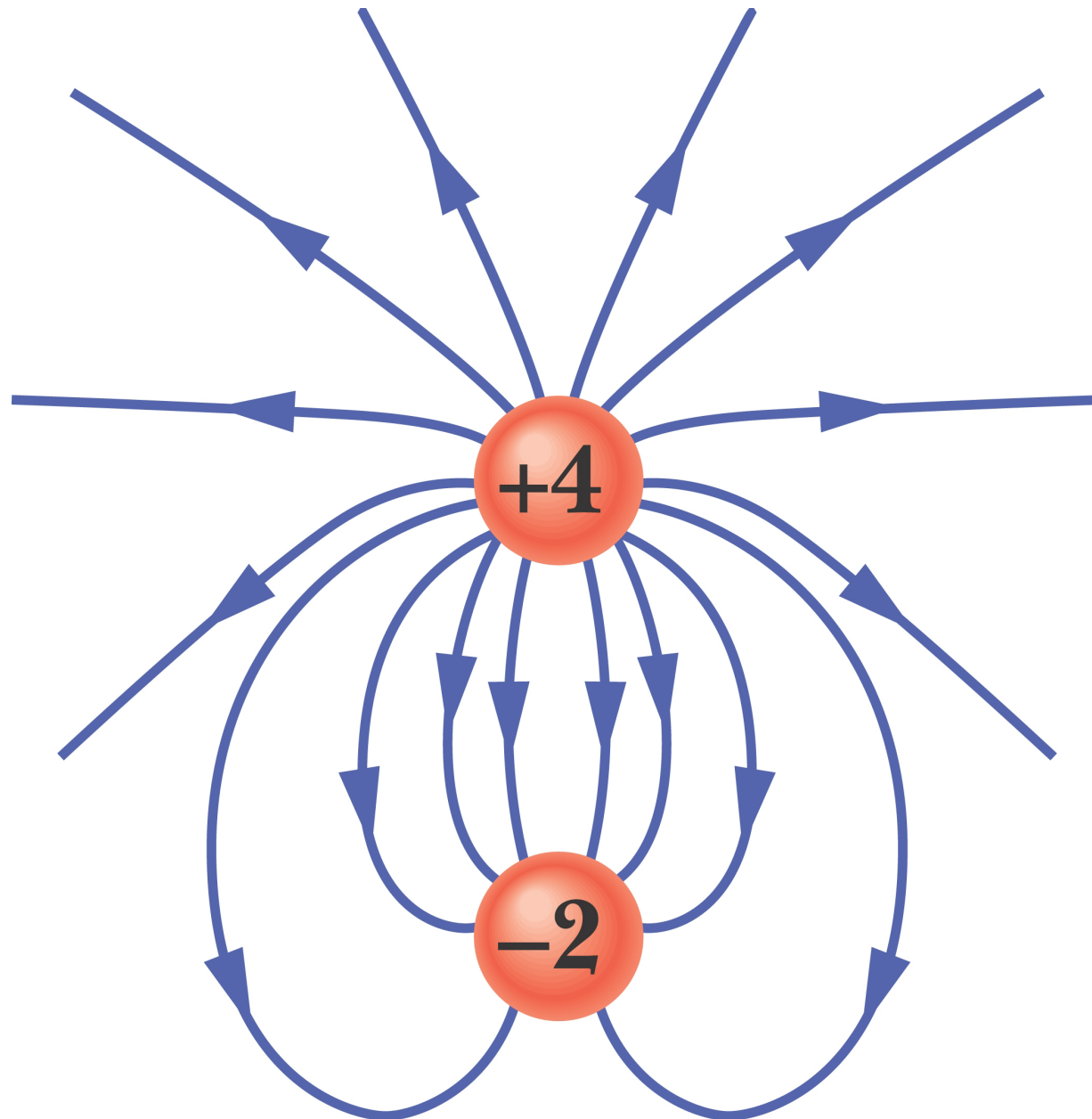
Activity 20.2.1 c.



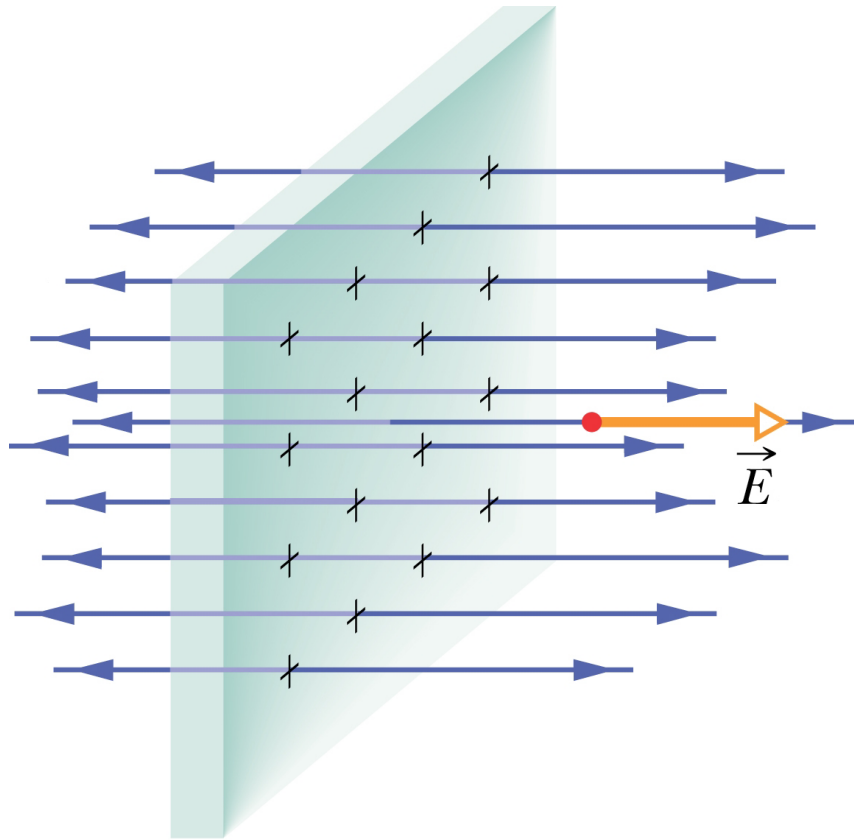
Another example (2 point charges).



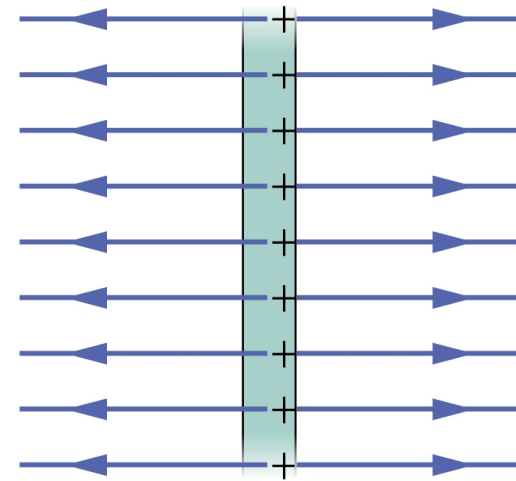
Yet another example (2 point charges, with unequal charge).



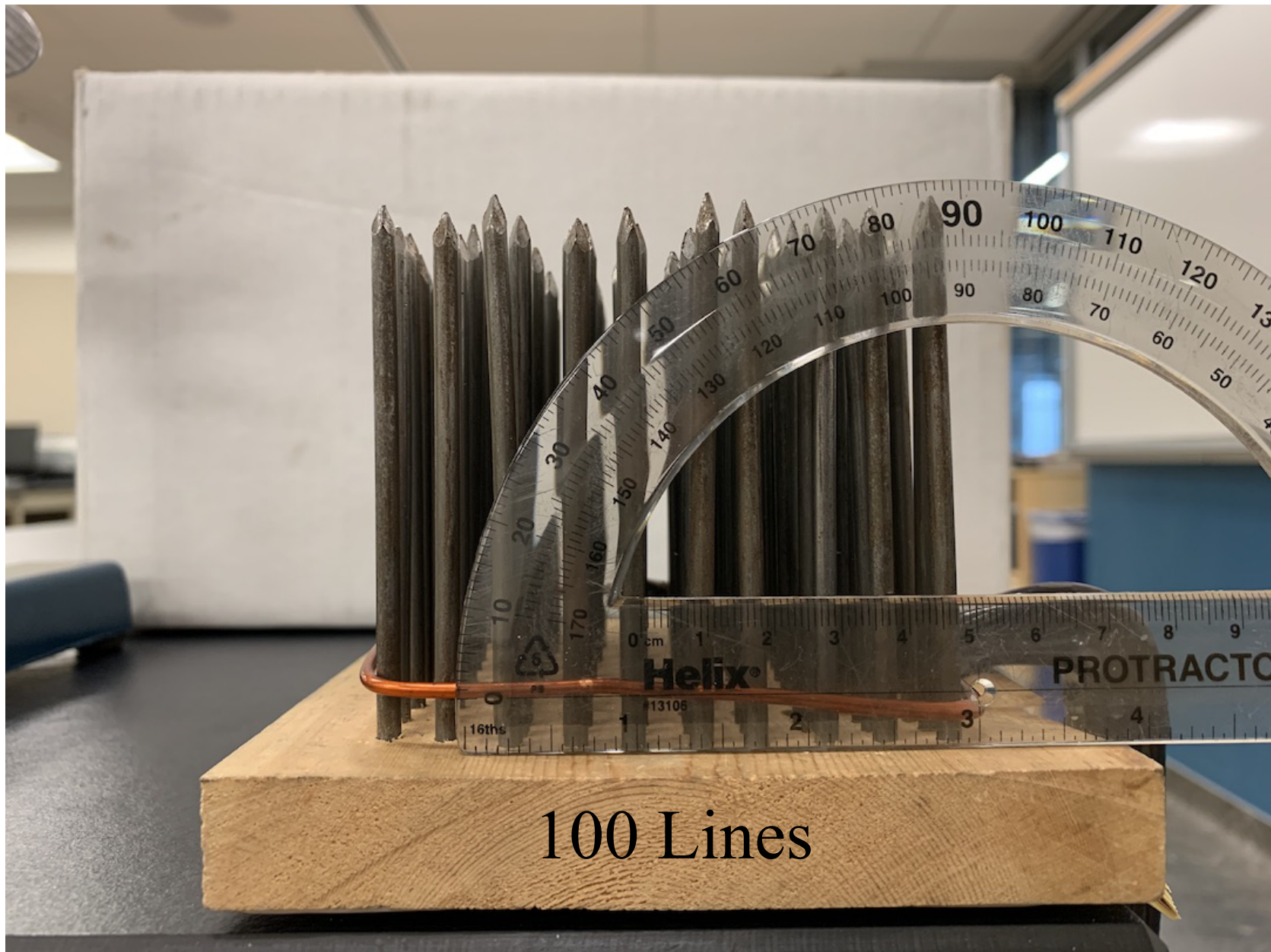
A last example (uniform charge distribution – sheet of charge).



(a)

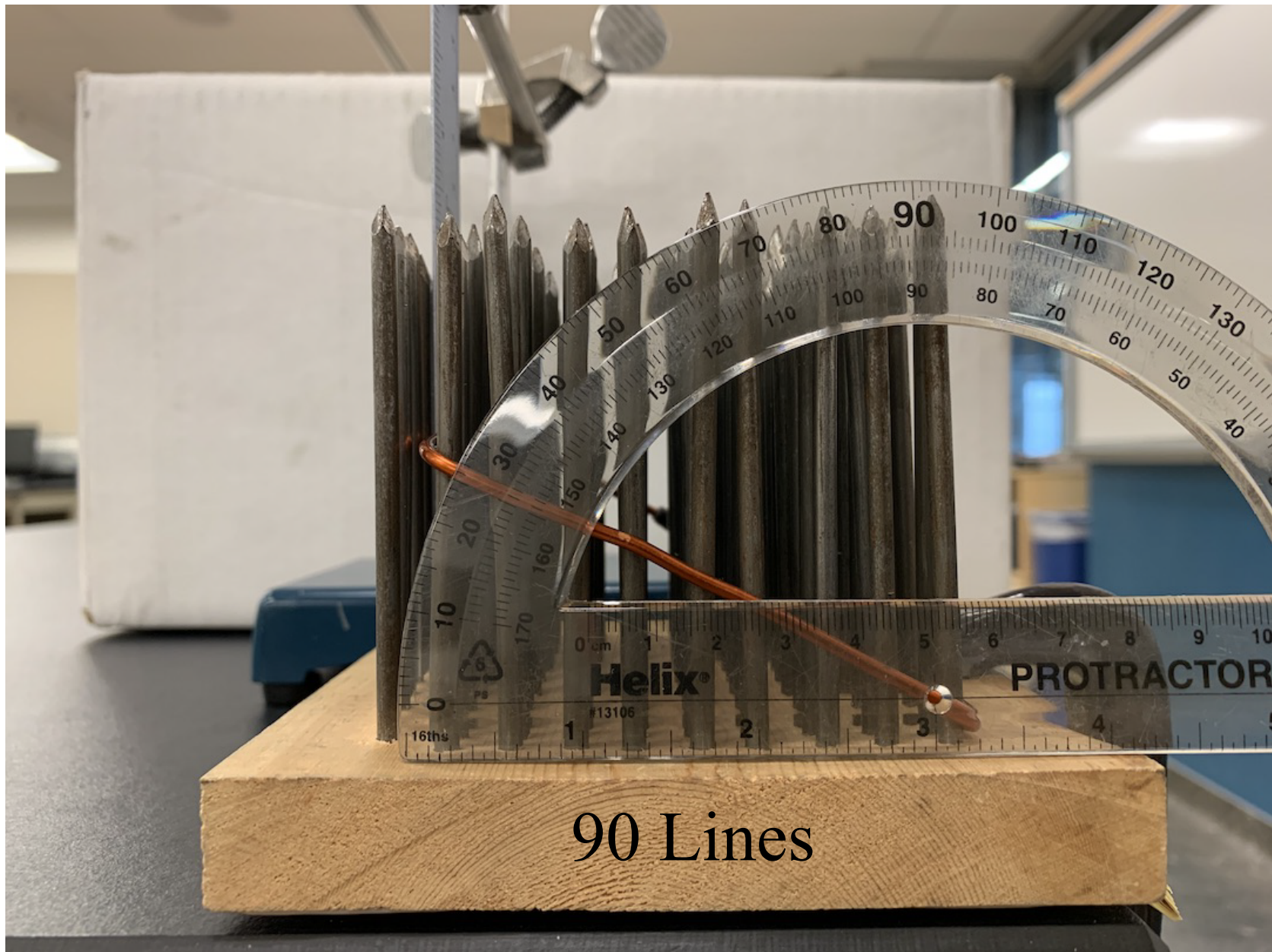


(b)

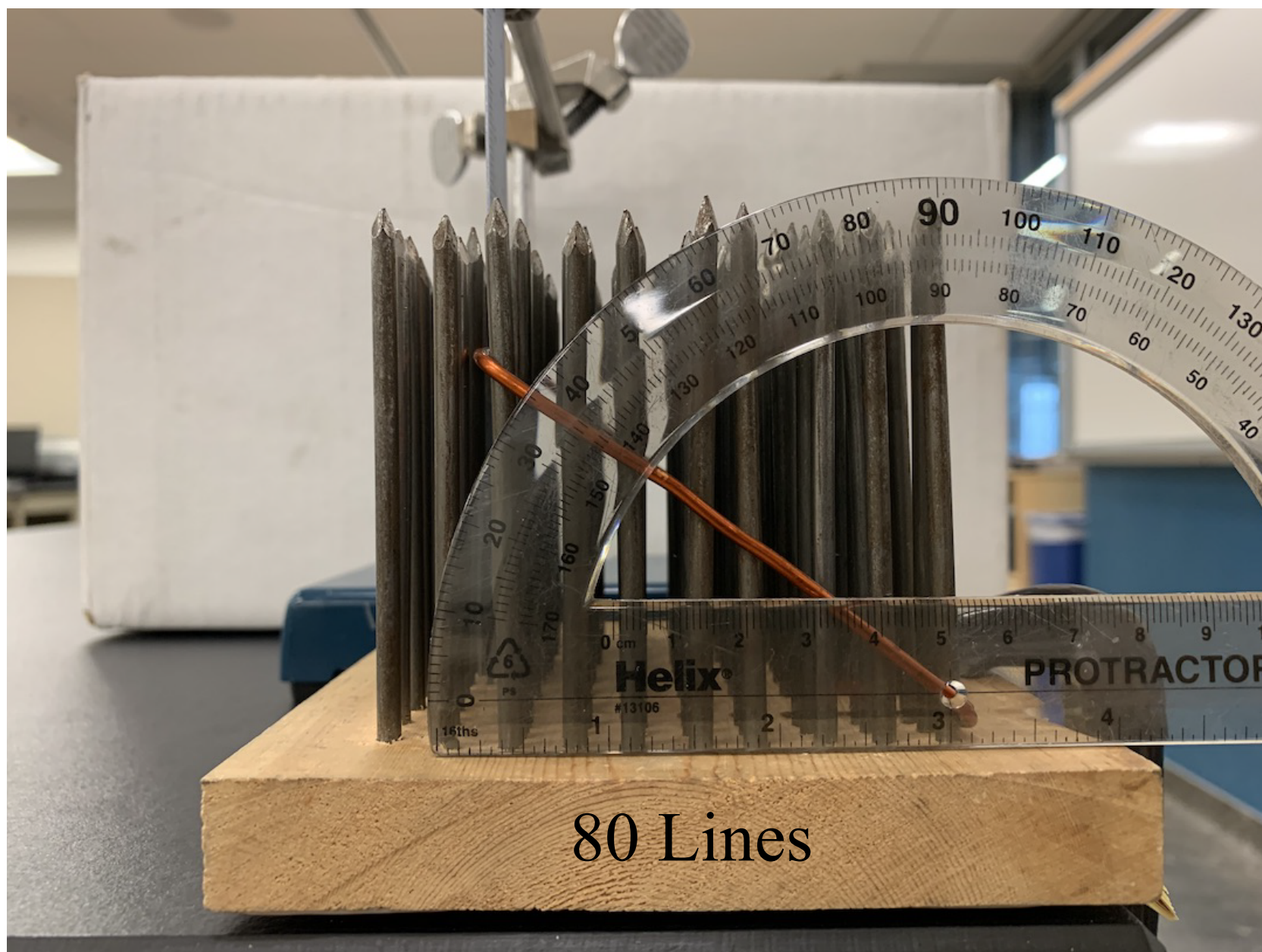


100 Lines

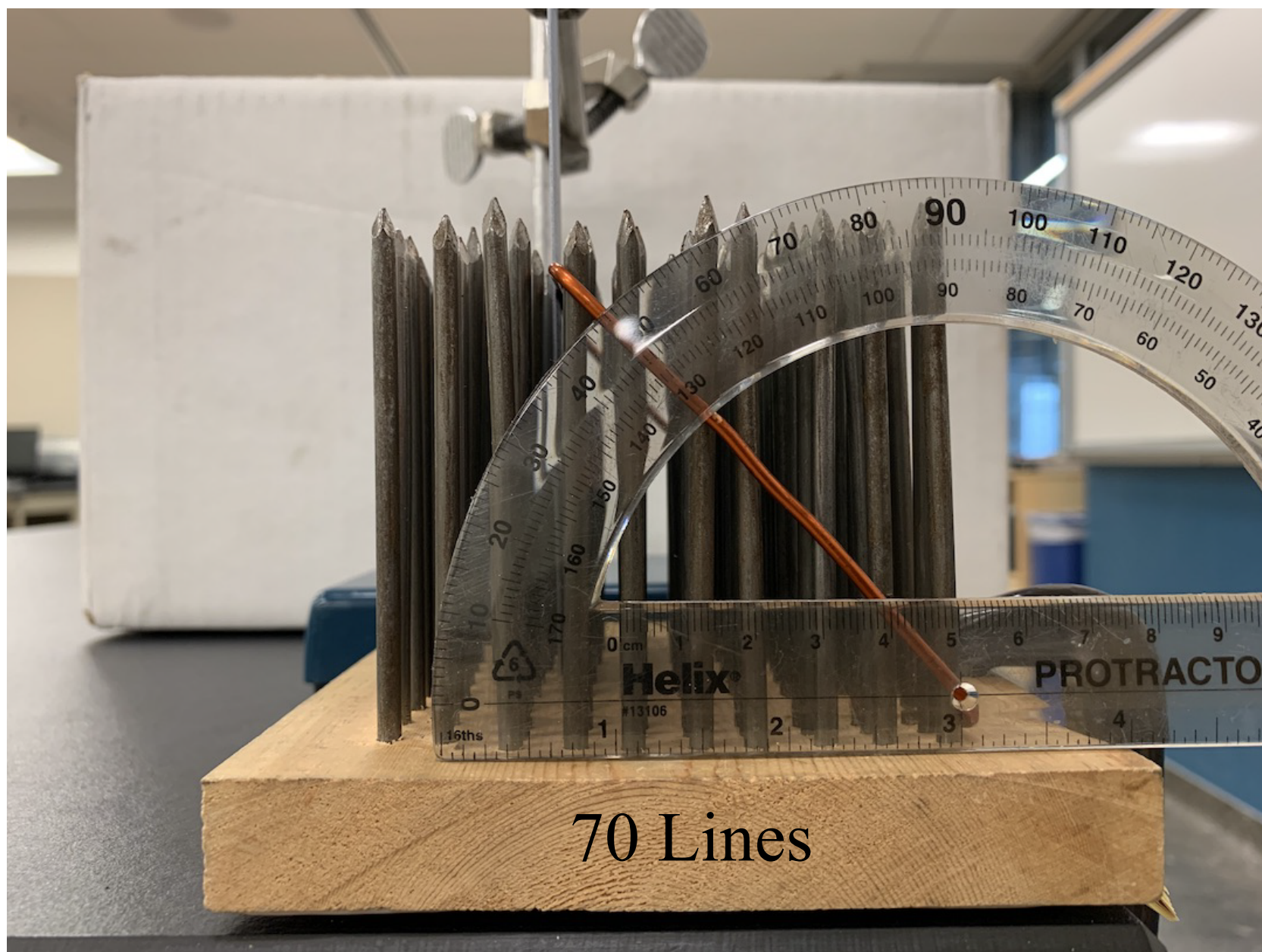




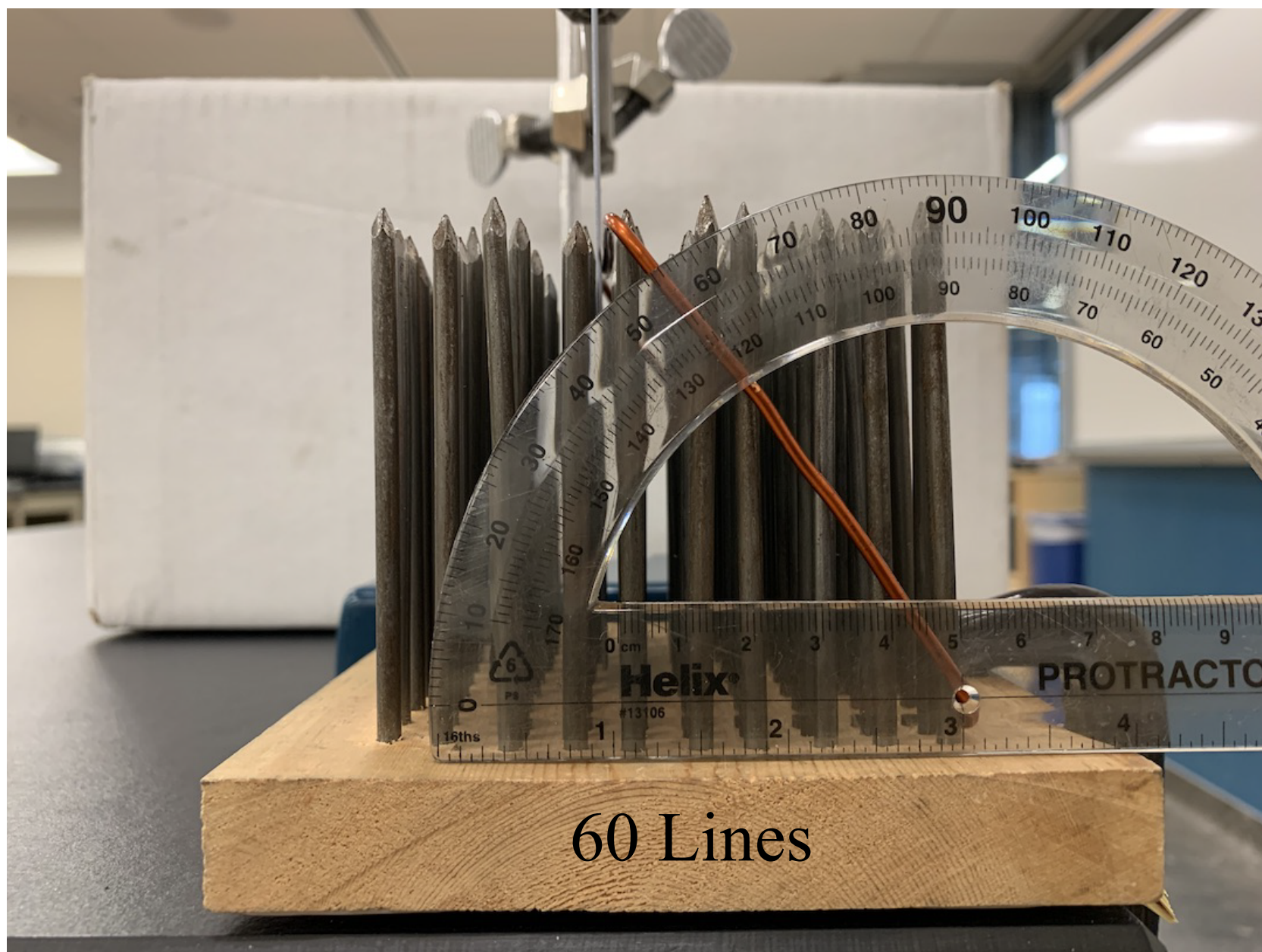
90 Lines





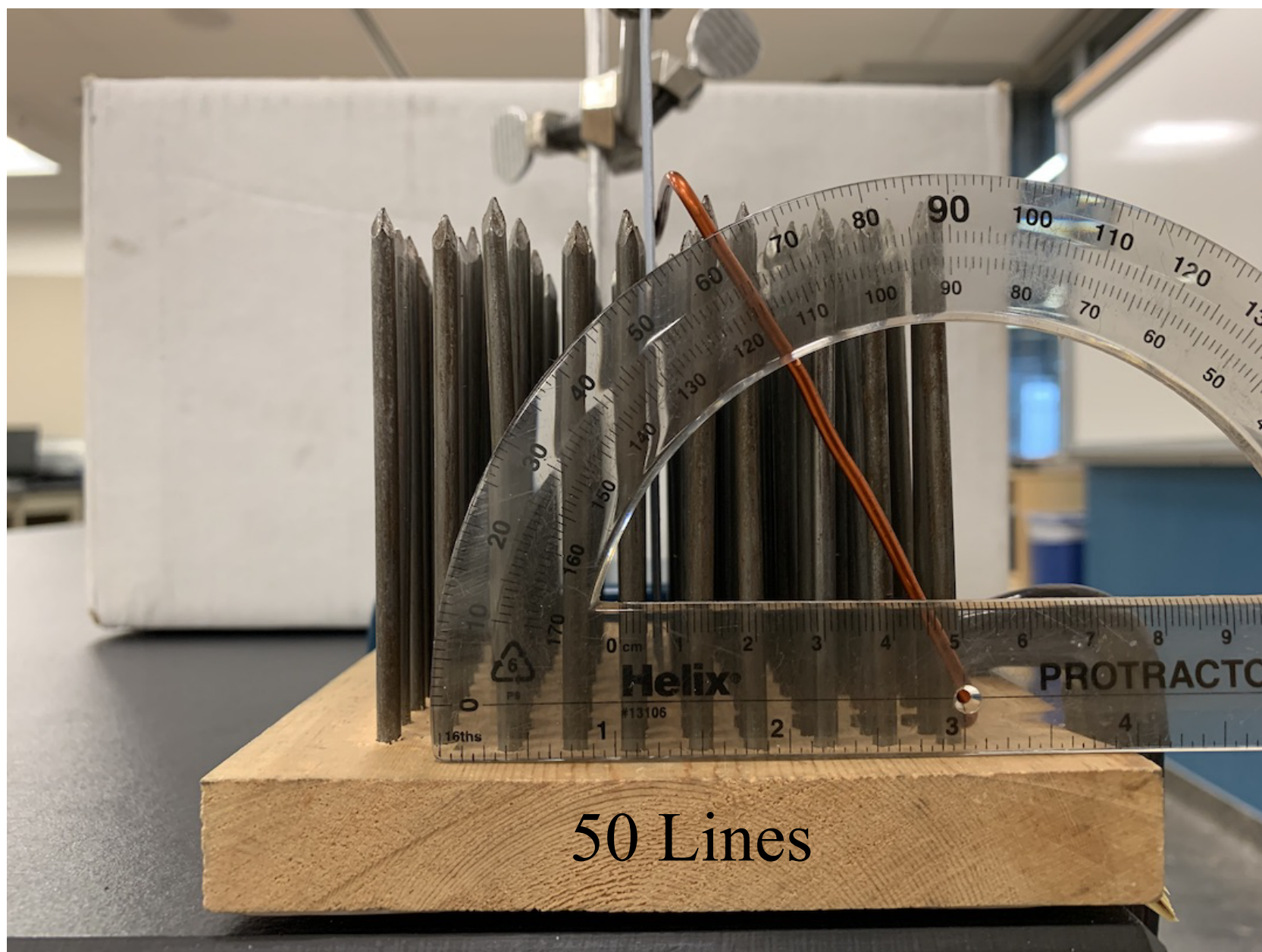


70 Lines

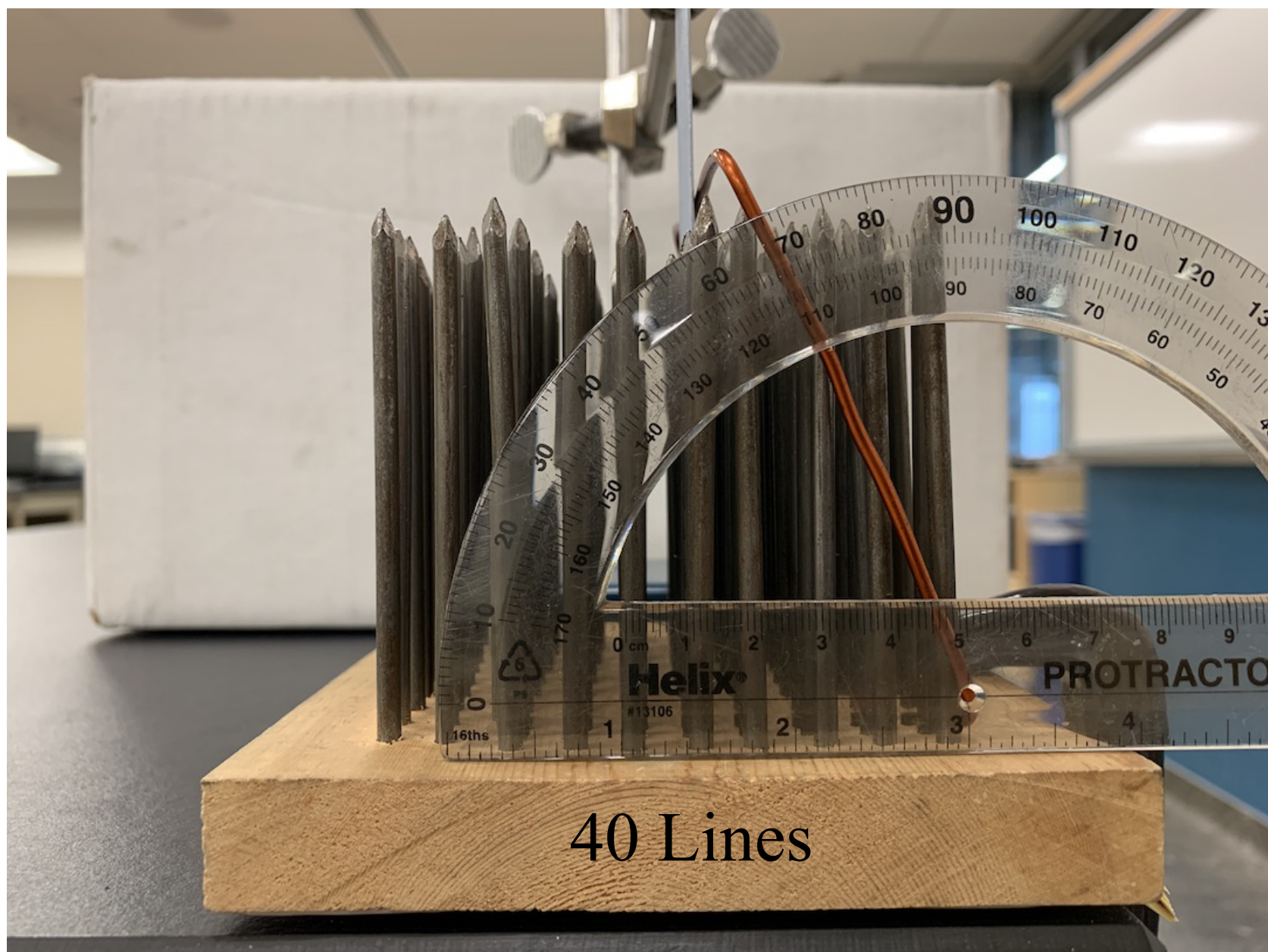


60 Lines



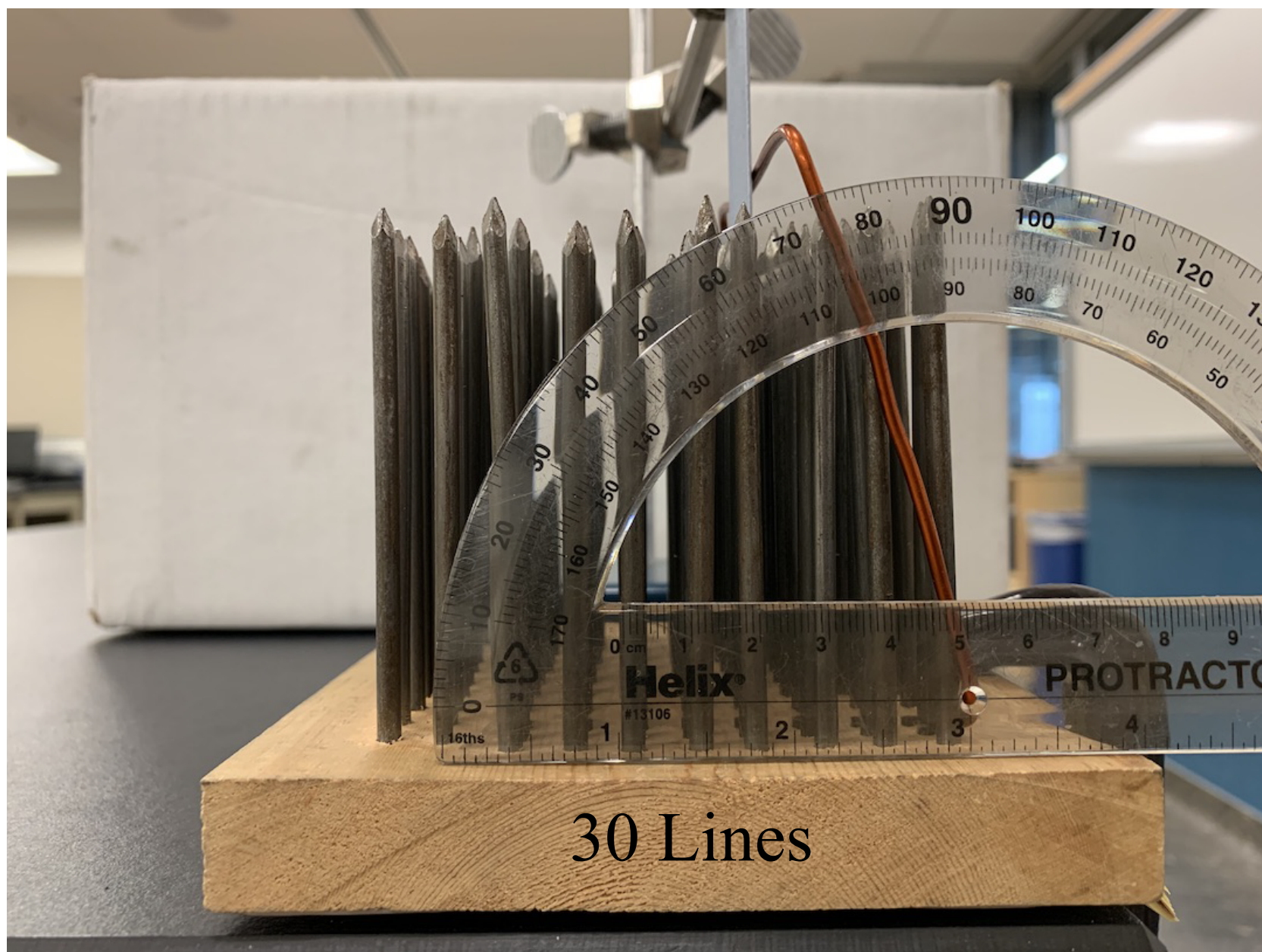


50 Lines

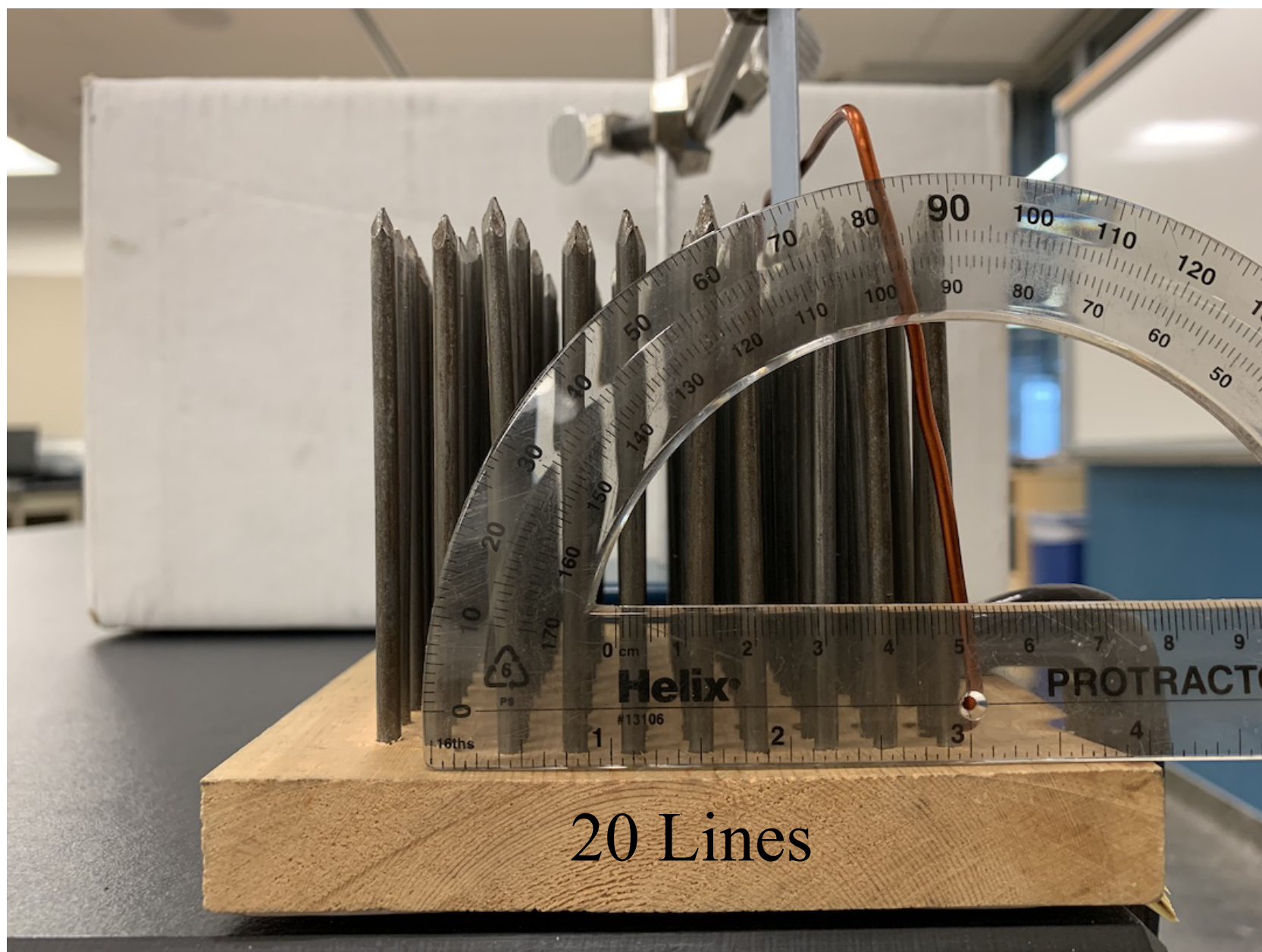


40 Lines



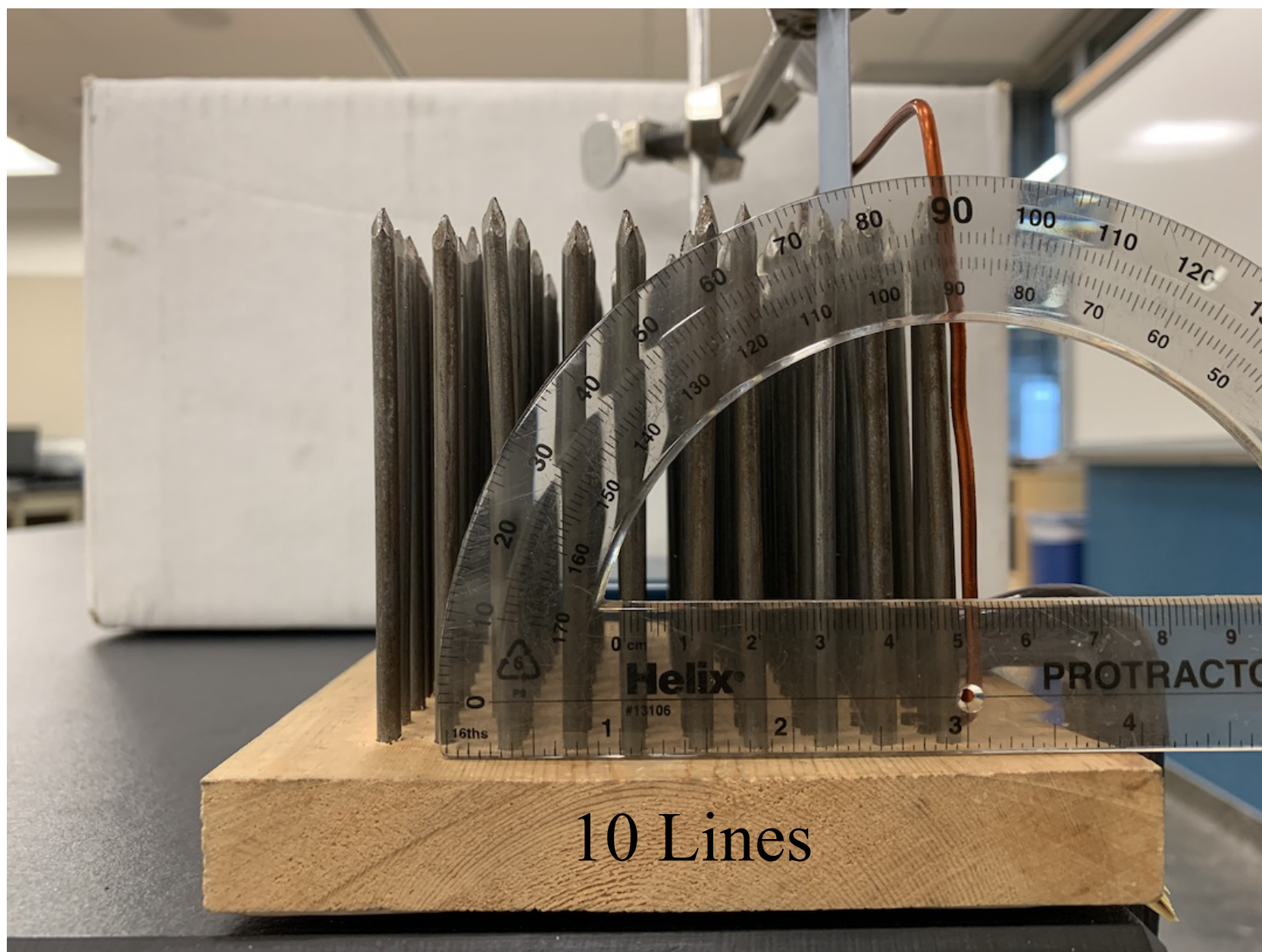


30 Lines

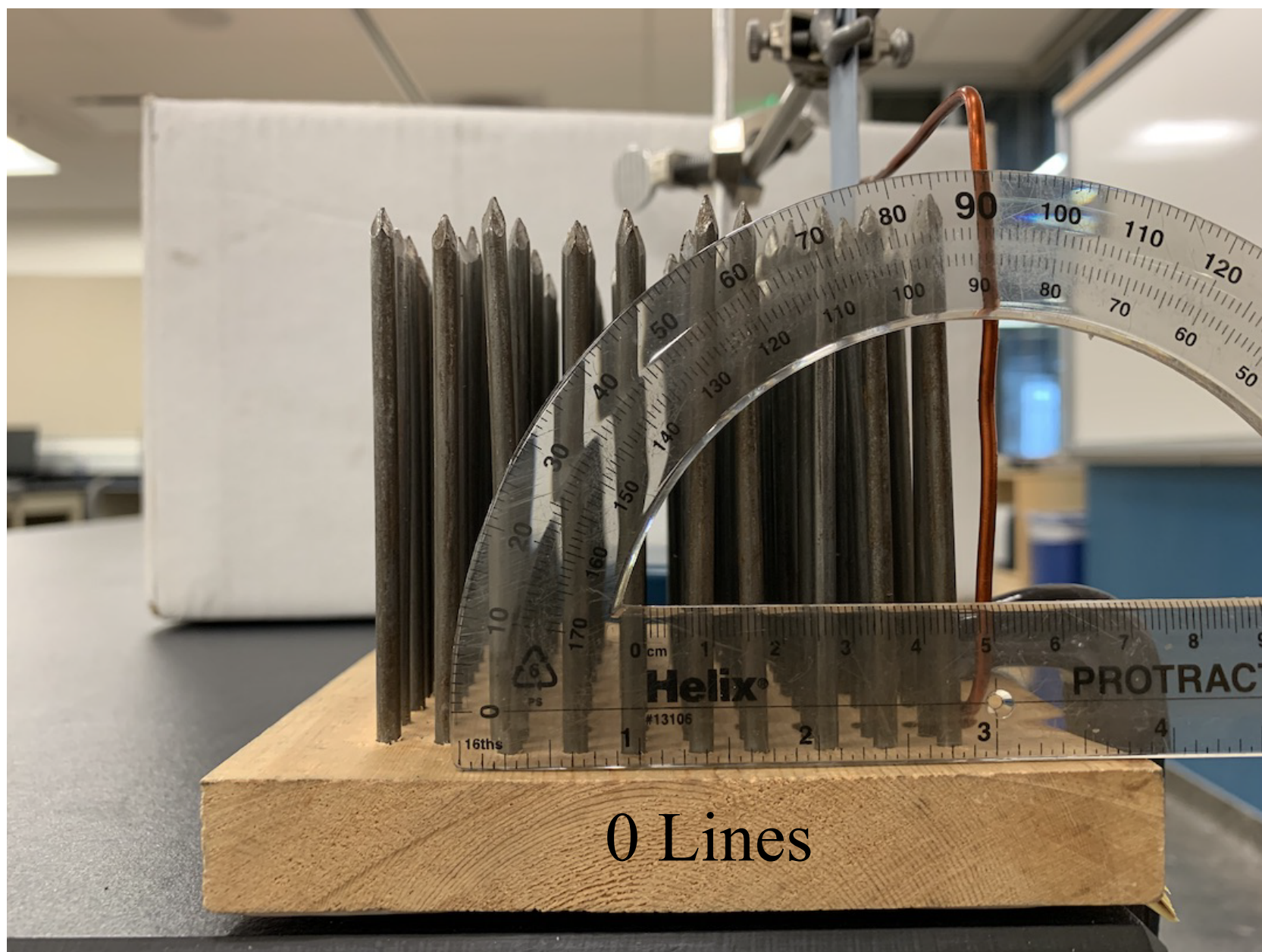


20 Lines





10 Lines



0 Lines