



Universiti Teknologi MARA  
Fakulti Sains Gunaan

# Introduction to Static Electricity

PHY407: A Physical Science Activity

Name: \_\_\_\_\_ HP: \_\_\_\_\_ Lab # 2:

The goal of today's activity is to explore and identify the relationship between charges, the electrical field created by those charges and the electrical forces the charges exert on other charges.

At the end of the activity, students will be able to:

1. Draw the electric force diagram exerted by one point charge onto another and describe the motion of charges in the presence of another point charge.
2. Describe how the strength of the force changes when the distance between the charges is varied.
3. Describe and produce a model for the electrical force in terms of the strength and direction that are acting between point charges.
4. Add and subtract forces vectorially and obtain the resultant force acting on a charged particle.
5. Describe and draw the electric field patterns created by a point charge.
6. Determine the strength of the electric field surrounding a point charge.
7. Produce a model for the electric field produced by point charges.
8. Describe and draw the electric field patterns surrounding two like point charges and two unlike point charges.

## Background Information

Our last investigation explored the methods of charging a neutral object by either friction (recall the rubbing of balloons with wool), contact (touching rubber or glass rod to a conducting sphere) or by induction (by polarization of the charges and grounding the side farthest from the charges source). We also explored the interaction between charged objects and observed that unlike charges attract each other and like charges repel each other.

Our investigation today will explore the actual cause of the interaction and the strength of that interaction. In addition, we will also explore, describe and obtain the vector nature of both the non-contact electrical forces (push or pull) and the invisible electric field which initiated that force. Since a force and a field line can be represented by an arrow { $\longrightarrow$ } to show the direction and its length to represent its strength, in today's activity, you will be drawing many arrows and compare the lengths of the arrows surrounding a charged particle. In addition, you will also be adding and subtracting these arrows numerically to obtain the sum or the resultant strength in either the horizontal (the x-axis) or the vertical (y-axis) direction. The direction will employ the use of trigonometry with inclination angle  $\{\theta\}$  or  $\{\phi\}$  while Pythagoras theorem will be employed to obtain the resultant length or strength of the electric fields and electric forces. The problem we are investigating in the activities today is how and what are the mechanisms that influence the dynamics of charged particles.



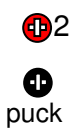
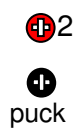
## Student Activity









### Investigation 1-Electrical (coulomb) force



#### **Prediction 1.1:**

Each of the positive charges in Figure 1.1 have the same strength (amount of charge) and are separated from the positive puck (also of the same strength) by a distance of 2.5 cm. Predict, by drawing the direction and strength of the force exerted by the charge on the puck. Draw the line,  $\longrightarrow$ , on the puck to indicate the force. Then predict and draw the direction of motion of the puck if it is allowed to move. (Note: Indicate the strength of the forces by drawing different lengths, short lines  $\{-\rightarrow\}$  mean smaller force and long lines  $\{\longrightarrow\}$  mean stronger force). [ALL predictions are to be done on the prediction sheet on page 13 onwards.]



**Table 1.1: Predicted and observed lines of forces and direction of motion for the positive puck**

Draw your predicted force	Draw your observed forces
 <p style="text-align: center;">Fig 1.1a</p>	 <p style="text-align: center;">Fig 1.1a</p>
<p>Draw the predicted direction of motion for the puck and state your reasons.</p>	<p>Draw the observed direction of motion for the puck.</p>
 <p style="text-align: center;">Fig 1.1b</p>	 <p style="text-align: center;">Fig 1.1b</p>
<p>Draw the predicted direction of motion for the puck and state your reasons.</p>	<p>Draw the observed direction of motion for the puck.</p>

Draw your predicted force	Draw your observed force
<p data-bbox="209 309 336 421">3   puck</p> <p data-bbox="427 734 539 768">Fig 1.1c</p>	<p data-bbox="818 309 946 421">3   puck</p> <p data-bbox="1046 734 1158 768">Fig 1.1c</p>
<p data-bbox="209 801 754 869">Draw the predicted direction of motion for the puck and state your reasons.</p>	<p data-bbox="802 801 1401 869">Draw the observed direction of motion for the puck.</p>
<p data-bbox="209 1350 336 1440">4   puck</p> <p data-bbox="427 1552 539 1585">Fig 1.1d</p>	<p data-bbox="818 1350 946 1440">4   puck</p> <p data-bbox="1046 1552 1158 1585">Fig 1.1d</p>
<p data-bbox="209 1619 754 1686">Draw the predicted direction of motion for the puck and state your reasons.</p>	<p data-bbox="802 1619 1401 1686">Draw the observed direction of motion for the puck.</p>

Draw your predicted force	Draw your observed force
 <p style="text-align: center;">Fig 1.1e</p>	 <p style="text-align: center;">Fig 1.1e</p>
<p>Draw the predicted direction of motion for the puck and state your reasons.</p>	<p>Draw the observed direction of motion for the puck.</p>

Each of the positive charges in Figure 1.1f have the same strength (amount of charge) and are separated from the positive puck (also of the same strength) by a distance of 1 cm, 2 cm, 3 cm and 4 cm respectively. Predict, by drawing the direction and strength of the force exerted by the charge on the puck. Draw the line,  $\longrightarrow$ , on the puck to indicate the force. Then predict and draw the direction of motion of the puck if it is allowed to move. (Note: Indicate the strength of the forces by drawing different lengths, short lines  $\{-\rightarrow\}$  mean smaller force and long lines  $\{\longrightarrow\}$  mean stronger force)

Draw your predicted forces	Draw your observed forces
 <p style="text-align: center;">Fig 1.1f</p>	 <p style="text-align: center;">Fig 1.1f</p>

Draw the predicted direction of motion for the puck and state your reasons.	Draw the observed direction of motion for the puck.
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### Activity 1.1:

Configure the charge you see in Figure 1.1a using the PhET simulation (Electric Field Hockey). Choose the *Practice option*, and click on the buttons *Trace* and *Puck is Positive* options. Bring a positive charge into position charge 1 placed 1 cm to the left of the puck. Use a ruler to measure the length of the force line (these lengths only represent the comparative strength of the force and not the actual magnitude of the force) on the puck. [I recommend that you print out a graph paper on a transparency and place the transparency on the screen. Then you don't need to use a ruler.] Then start adding charge 2, 3 and 4, all at a distance of 1 cm from the puck as shown in Fig 1b through Fig 1e. For each case, draw the observed force lines and the initial direction of motion of the puck. [You need to click on **START** to move the puck and the **RESET** button to repeat or reset the simulation. **DO NOT** press the **CLEAR** button until you complete part (e).

Draw the observed lines of force and the initial direction of the puck in Table 1.1. In addition, record the length of the force line (strength of the force) in Table 1.2.

**TABLE 1.2: Electric force on a charged puck with 4 charges placed 1 cm surrounding it**

L represents strength of force	r, cm			
	1	1	1	1
L, cm				

Configure the charge you see in Figure 1.1f. Start moving the puck from 1 cm below the charge in increments of 0.2 cm until the charge is 4 cm below the puck. Record your measurements of L in Table 1.3. Reproduce the tables below in EXCEL so that you can do the analysis shown. [You may download the EXCEL template I had developed.]

**TABLE 1.3: Electric force, inverse of charge separation, ratios of forces and square of distances on a charged puck with a charge moving away from it**

r, cm	L, cm	$1/r, m^{-1}$	$1/r^2, m^{-2}$	$L_{n+1}/L_n$	$(r_n/r_{n+1})^2$
100					
120					
140					
160					
180					
200					
220					
240					
260					
280					
300					

r, cm	L, cm	1/r, m <sup>-1</sup>	1/r <sup>2</sup> , m <sup>-2</sup>	L <sub>n+1</sub> /L <sub>n</sub>	(r <sub>n</sub> /r <sub>n+1</sub> ) <sup>2</sup>
320					
340					
360					
380					
400					

### Questions

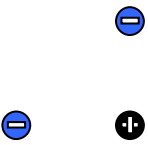
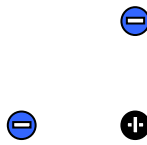
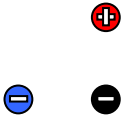
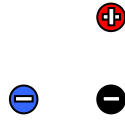
1. How is your prediction in the drawing for the force direction and strength of the force different from your observation?
2. Is there a relationship between the strength of the force and the distance separating the charge and the puck? What relationship do you observe?
  - Use Microsoft Excel™ to plot a graph of L vs. r, L vs. 1/r, L vs. 1/r<sup>2</sup> and L<sub>n+1</sub>/L<sub>n</sub> vs. (r<sub>n</sub>/r<sub>n+1</sub>)<sup>2</sup>. Explain the relationship represented. Based on the results and the graphs, suggest a mathematical model (write a math formula to represent the relationship) for the electric force as a function of the distance separating 2 charges.
3. How does the time for the puck to travel a distance of, say, 20 cm, affected by the length of the force line?
4. How would the strength of the force vary if the quantity of charge is increased or decreased? What is the relationship between F and the amount of charge? [The PHeT simulation may not be able to show this relationship but you are encouraged to try out simulations from The Physics Classroom website or any other relevant websites.]

### Investigation 2 - Sum of forces

#### Prediction 2.1:

Draw the forces acting on the charge at the center. The separation between the charge at the center and the other two charges are equal (1 cm). Then draw your prediction for the direction of motion of the charge at the center when it is allowed to move. [When you run the simulation, draw the observation for both the lines of forces and the direction of motion.]

**Table 2.1: Predicted and observed lines of force and direction of motion for the puck**

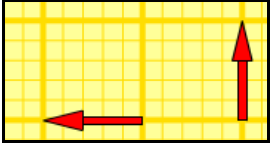
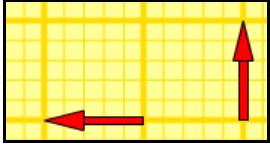
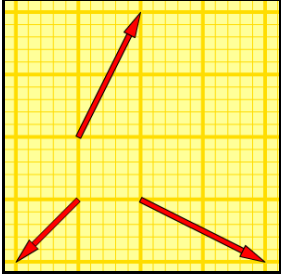
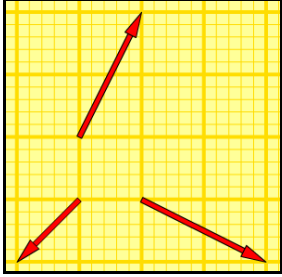
	Prediction	Observation
Case 1	 <p>Fig 2.1a</p>	 <p>Fig 2.1a</p>
Case 2	 <p>Fig 2.1b</p>	 <p>Fig 2.1b</p>

**Activity 2.1:**

Configure the charges as in Figure 2.1a followed by charges in Figure 2.1b using the PhET simulation ( Electric Field Hockey). Draw the forces you observed acting on the charge in the middle of the configuration (the puck or hockey ball). Then draw the direction of motion you observed.

**Prediction 2.2:**

1. Draw your prediction of the horizontal component for the force pulling or pushing a particle due north along the positive y-axis and the vertical component for the force pulling or pushing the same particle due west along the negative x-axis shown in Figure 2.2a. Then, draw your prediction for the resultant force in Fig 2.2a
2. Draw your prediction of the horizontal and vertical components for each of the forces shown in Figure 2.2b. Then draw the prediction for the sum of the horizontal and the sum of the vertical forces. Finally, draw your prediction for the resultant force in Fig 2.2b.

	Prediction	Observation
Case 1	 <p>Fig 2.2a</p>	 <p>Fig 2.2a</p>
Case 2	 <p>Fig 2.2b</p>	 <p>Fig 2.2b</p>

**Activity 2.2:**

Configure the forces in Figure 2.2a followed by the forces in Figure 2.2b using the PhET simulation (from the PHET-Vector-Math). Then reveal the horizontal and vertical forces for each of the force in Figure 2.2 by clicking on the button *style 1 or style 2*. Record the angles between the components and the individual force. Then reveal the sum of the forces along the horizontal and along the vertical. Finally reveal the resultant force for each case. Compare these to your predictions.

**Questions**

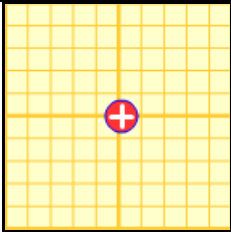
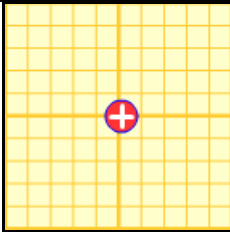
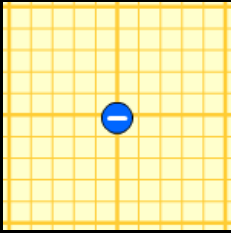
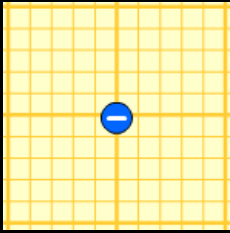
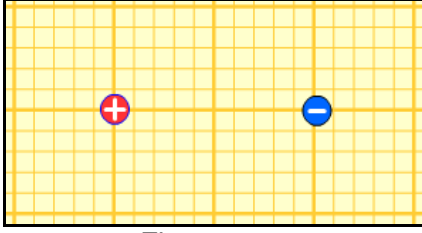
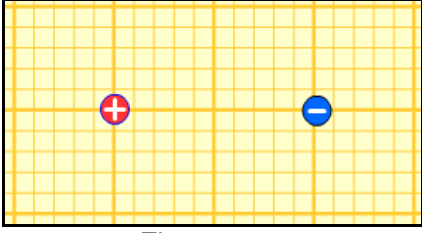
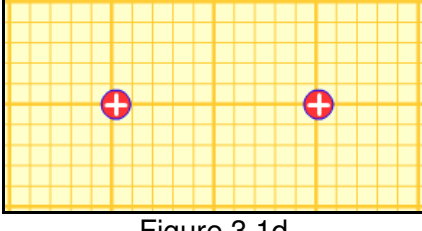
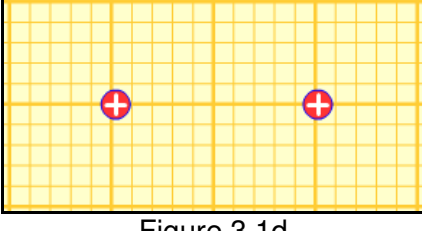
1. Does a force pointing along the x-axis have any vertical component?
2. Does a force pointing along the y-axis have a horizontal component?
3. If a force is not acting along the horizontal or vertical direction, what should you do to the force if you need to determine a resultant force if there is more than 1 force acting on a particle?
4. How do you find the horizontal and vertical components for each force respectively?

5. How do you determine the total horizontal and the total vertical components of the resultant force?
6. Will specifying the strength alone be sufficient to describe the resultant force? If not, what else is required and how would you do it?
7. What can you conclude about the initial motion of the charged particle that is subjected to the total force in the activities above?

### Investigation 3-Electric fields

#### **Prediction 3.1:**

Draw the electric field lines (represented by  $\{-\rightarrow\}$  to indicate smaller field and longer lines  $\{\longrightarrow\}$  to indicate stronger field) around the charged particle at the center of the grid for each of the cases in Figure 3.1.

	Prediction	Observation
Case 1	 Figure 3.1a	 Figure 3.1a
Case 2	 Figure 3.1b	 Figure 3.1b
Case 3	 Figure 3.1c	 Figure 3.1c
Case 4	 Figure 3.1d	 Figure 3.1d

#### **Activity 3.1:**

Configure the charges in the PhET simulation (Charges-and-Field). Draw the field lines you observed for each of the cases in Figure 3.1.



### Questions

- How is your prediction different from your observation for each of the case?
- Is there a region of space where the field is zero in Figure 3.1c and Figure 3.1d? Explain your answer.
- What would happen to a test charge  $+q$  if it is placed
  - near the charge in Figure 3.1a?
  - Near the charge in Figure 3.1b?
  - Equidistantly placed between the charges in Figure 3.1c?
  - Equidistantly placed between the charges in Figure 3.1d?
- How would this field be associated with the force in Activity 1 and 2? Write down the relationship.

### Prediction 3.2:

Predict how the strength of the electric field changes at a radius of 20 cm when there is only 1 charge, when the charge is doubled and when the charge is tripled Then repeat your prediction at radii of 40 cm, 60 cm, 80 cm and 100 cm around the charged particle. Note that 1 small box represents 10 cm.

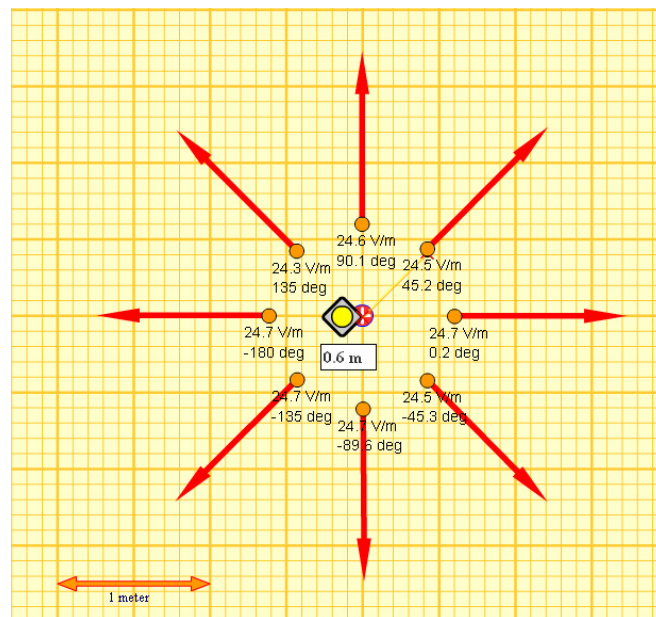


Figure 3.2a

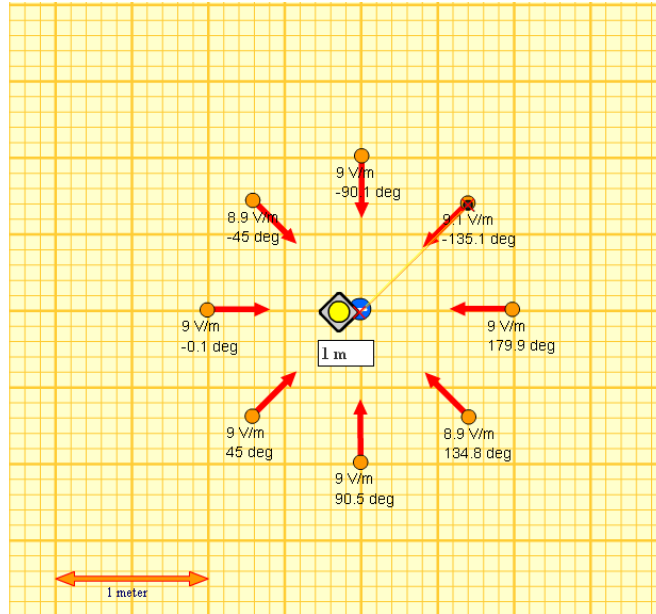


Figure 3.2b

**Activity 3.2:**

Configure the charge for the case shown in Figure 3.2a using the PhET simulation (Charges-and-field). Use the electric field sensors to measure the electric field strength at each of the radii 20 cm until 200 cm in increments of 10 cm. Record the values (you will need to take the average readings) in Table 3.2. In addition, calculate the following quantities:  $1/r$ ,  $(1/r)^2$ , the ratios  $E_{n+1}/E_n$ , and  $(r_n/r_{n+1})^2$ .

**TABLE 3.2.1: Electric field around charge q**

r, cm	E, V/m	$1/r, m^{-1}$	$1/r^2, m^{-2}$	$E_{n+1}/E_n$	$(r_n/r_{n+1})^2$
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

Now observe the electric field strength at the various locations when another charge is added at the same position as the initial charge.

**TABLE 3.2.2: Electric field around charge 2q**

r, cm	E, V/m	$1/r, \text{m}^{-1}$	$1/r^2, \text{m}^{-2}$	$E_{n+1}/E_n$	$(r_n/r_{n+1})^2$
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

**TABLE 3.2.2: Electric field around charge 3q**

r, cm	E, V/m	$1/r, \text{m}^{-1}$	$1/r^2, \text{m}^{-2}$	$E_{n+1}/E_n$	$(r_n/r_{n+1})^2$
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					
130					
140					
150					
160					
170					
180					
190					
200					

**Questions**

1. How was your prediction compare to the data you collected?
2. Is there a relationship between the electric field strength and the position from the charge producing it? [Enter your data into EXCEL. Try taking the ratios of E ( $E_{n+1}/E_n$ , ...,  $E_9/E_8$  until  $E_2/E_1$ ) and compare to the ratios of square of the position ( $(r_n/r_{n+1})^2$ , ...,  $(r_8/r_9)^2$ , until  $(r_1/r_2)^2$ ]. What relationship do you observe? Sketch a graph of E vs. r, E vs.  $1/r$ , E vs.  $1/r^2$  and  $E_{n+1}/E_n$  vs.  $(r_n/r_{n+1})^2$  for the charge q. Explain the relationship represented. Based on the results and the graphs, how would E be mathematically modeled as a function of distance measured from the charge?
3. How would the field strength vary if the charge producing it is increased or decreased? What is the relationship between E and the amount of charge?

**Predictions Worksheet for Lab #2**  
**Electrical Forces, Adding Forces and Electrical Field**

Draw your predicted forces

1    
puck

Fig 1.1a

Draw the predicted direction of motion for the puck and state your reasons.



 2  
  
puck

Fig 1.1b

Draw the predicted direction of motion for the puck and state your reasons.

Draw your predicted force

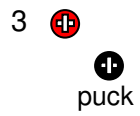


Fig 1.1c

Draw the predicted direction of motion for the puck and state your reasons.



Fig 1.1d

Draw the predicted direction of motion for the puck and state your reasons.

Draw your predicted force



Fig 1.1e

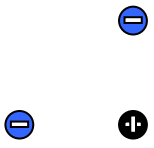
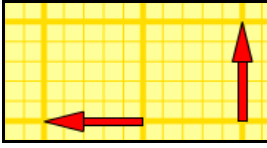
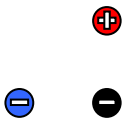
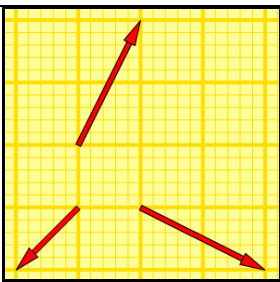
Draw the predicted direction of motion for the puck and state your reasons.



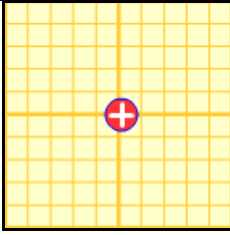
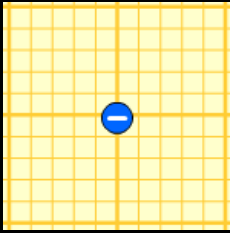
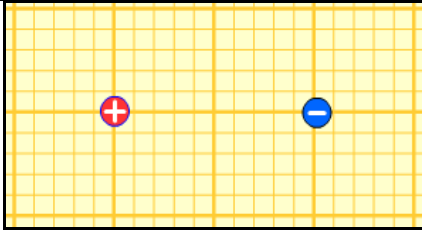
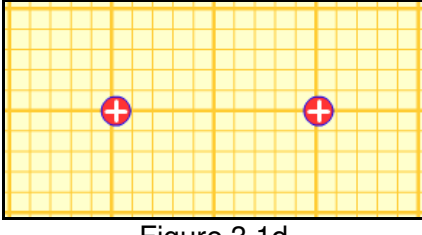
Fig 1.1f

Draw the predicted direction of motion for the puck and state your reasons.

Prediction 2

	Prediction 2.1	Prediction 2.2
Case 1	 <p>Fig 2.1a</p>	 <p>Fig 2.2a</p>
Case 2	 <p>Fig 2.1b</p>	 <p>Fig 2.2b</p>



Prediction 3.1	
Case 1	 Figure 3.1a
Case 2	 Figure 3.1b
Case 3	 Figure 3.1c
Case 4	 Figure 3.1d

Prediction 3.2