Laboratory 1: Electric Charges – Activity

Electromagnetism describes interactions between charged objects. A first step in understanding electromagnetism is to classify the possible types of charged object and provide methods for determining the type of charge that any object may have.

A complete classification can be attained by observing the forces exerted by various charged objects on each other. This laboratory focuses on the qualitative aspects of classifying charged objects and their interactions.

1 Electrostatic properties of pulled tape

The important qualitative features of electrostatics can be illustrated with strips of scotch tape prepared in two distinct ways.

a) Prepare a U-type strip of tape (see page 8) and suspend it from the desk. Note that the tape's important electrostatic properties typically persist for upwards of 10 minutes after preparation unless the tape is rubbed or lies in contact with a surface. Thus **minimize contact between the tape and its surroundings after preparation.**

b) Place various objects (e.g. a pen, a piece of paper, your hand) near to, but not touching, the strip of tape. Describe the effects of these on the tape.

If there are **no effects** on the tape, then this indicates that the **preparation or storage of the tape was defective**. This is one way of verifying that the tape is correctly prepared.

c) Attach a small piece of paper to a thread. Suspend the paper near to, but not touching, the tape. Describe what happens to the tape and the paper. The effect is weak but noticeable. If the paper touches the tape the effect may be reversed (if this happens rub the paper with your finger and repeat the preparation process).

During the preparation process the tape has clearly acquired a property which enables it to exert attractive forces on surrounding objects. This tape is **electrically charged**.

2 Electrostatic properties of two pieces of U-type tape

The goal of the next series of exercises is to **develop** a set of rules (rather than **use** a set of known rules) that describes how charged objects interact. At this stage you should assume that you **do not know** any rules for charge interactions that you may have encountered in class, e.g. "Like charges . . . , unlike charges, ..." You must not use rules like this to explain your answers.

To do this you will need to reason about the charges of objects **independently** of observing them interact. Then you will have to observe them **independently** of knowing anything about their charges. Combining your conclusions and observations will allow you to state general rules for how charged objects interact.

a) In a while, you will prepare two U-type pieces of tape. **Without preparing them, observing them or using any rules of electrostatics that you may have encountered in class**, which of the following would you say is true?

   i) The tapes will be oppositely charged.

   ii) The tapes will either be both charged with the same type of charge or both uncharged.

   Explain your answer.

b) Prepare the two U-type pieces of tape and hold them near to each other. Which of the following do you observe?

   i) The tapes attract.

   ii) The tapes repel.

   iii) There is no interaction between the tapes.

c) Move one of the pieces of U-type tape around the other. Does the interaction between the two depend on their relative orientations?

3 Electrostatic properties of two pieces of L-type tape

a) You will prepare two L-type pieces of tape. **Without preparing them, observing them or using any rules of electrostatics that you may have encountered in class**, which of the following would you say is true?

i) The tapes are oppositely charged.

ii) The tapes are either both charged with the same type of charge or they are both uncharged.

Explain your answer.

b) Prepare two L-type pieces of tape and hold them near to each other. Which of the following do you observe?

i) The tapes attract.

ii) The tapes repel.

iii) There is no interaction between the tapes.

4 Electrostatic properties of an L-type tape and a U-type tape

In a while you will observe the interaction between an L-type and a U-type piece of tape. Reasoning about the charges of these types of tape requires the idea that, in any isolated collection of objects, the overall charge must stay the same although charges may be redistributed amongst the objects.

a) You will prepare an L-type tape and a U-type tape. **Without preparing them, observing them or using any rules of electrostatics that you may have encountered in class**, which of the following would you say is true?

i) The tapes are oppositely charged or they are both uncharged.

ii) The tapes are both charged with the same type of charge.

Explain your answer.

b) Bring an L-type tape near a U-type tape. Which of the following do you observe?

i) The tapes attract.

ii) The tapes repel.

iii) There is no interaction between the tapes.

5 General interactions between tape types

The observations of the interactions between all possible combinations of types of tape can be condensed into a single rule regarding electrostatic interactions.

a) Based on your observations, how do two types of tape which have the same type of charge interact? Describe which of the observations from the previous sections support your answer.

b) Based on your observations, how do two types of tape which have different types of charge interact? Describe which of the observations from the previous sections support your answer.

6 Exact nature of charge on the tapes

The nature of the charges on the U and L-types of tape can be determined by bringing an object, whose type of charge is known into proximity with the tapes.

a) Suspend a U and an L-type piece of tape from the underside of the desk. Rub a plastic object (but **not** a pen containing ink) on (non-synthetic) fabric and bring

it near to the each of the pieces of tape. Based on your observations, which type of tape has the same charge as the plastic?

b) It is known that the rubbed plastic is negatively charged. Based on this, describe the charges on the two types of tape.

Type	Charge
U	
L	

7 Electrostatic polarization

A bulk object may contain many charged particles and often the total quantity of positive charge matches that of negative charge. Such objects are, in bulk, electrically neutral but they can still exert and feel electrostatic forces. The aim of this part of the laboratory is to observe and explain this.

a) Construct a pendulum by suspending a small piece of paper from a thread. Repeat this so that you have two pendulums. Hold the pairs of objects, listed in the table below, near to each other and observe and describe the directions of the forces.

Objects	Force direction
Pendulum and pendulum	
Pendulum and U-type tape	
Pendulum and L-type tape	

b) **Based on your observations** are the pendulums charged or not? If so, what type of charge could each have?

The paper consists of molecules and in each of these the charge may not be uniformly distributed. A simple model for such a molecule is illustrated in Fig. 1. Such a molecule is said to be **polarized** and is called an **electric dipole.**

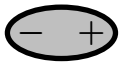
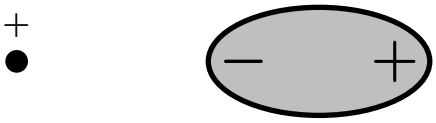


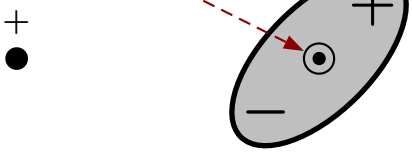
Figure 1: Electric dipole

c) Suppose that an electric dipole is placed near to another charged particle in the illustrated configuration. Draw the two force vectors, **with the correct relative sizes**, for the forces exerted on the charged particle by each end of the dipole. Explain what happens to the charged particle if it is initially at rest.



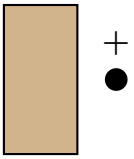
d) Draw the force vectors for the forces exerted on the two ends of the electric dipole by the charged particle. Explain what happens to the electric dipole if it is initially at rest.

e) Now consider a dipole which can pivot about a stationary axle through its center as illustrated below. Draw the force vectors, **with the correct relative sizes**, for the forces exerted on the two ends of the electric dipole by the charged particle. Explain what happens to the electric dipole if it is initially at rest.



f) The paper contains electric dipoles. In the absence of any charged object how do you expect the dipoles would align?

g) Suppose that the paper is held near to a charged object. Sketch several dipoles in the paper in the schematic diagram indicating their orientation after accounting for the effects of the charged object. Use this to describe whether the charged object exerts a net force on the paper and, if so in what direction of the force. Explain your answer.



Paper

h) Repeat part g) for the case where the charged object is negative.

i) Are these predictions consistent with your observations of the interactions between tapes and pendulums?

8 Preparing the Tape

There are two types of tape that need to be produced. The methods of producing both types of tape utilize a **base layer** of tape. In order to make the **base layer** proceed as follows.

a) Stick an entire 20 cm long strip of tape to the surface of the desk. Gently rub the tape several times with your finger. The effects that this accomplishes are accentuated by first breathing on your hand (this is not magic - there is a good reason for this).

In order to make an "upper" or **U-type** piece of tape proceed as follows:

a) Gently rub the base layer with your finger several times.

b) Remove a 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the base layer and gently rub it with your finger several times. Label it "U."

c) Quickly pull the U tape off the base layer. Minimize contact between the tape and any surrounding objects. Store the tape by suspending it from one end from the underside to the desk for later use.

In order to make a "lower" or **L-type** piece of tape proceed as follows:

a) Gently rub the base layer with your finger several times.

b) Pull a 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the base tape and gently rub it with your finger several times. This will form an "lower" type tape. Label it "L."

c) Pull a third 20 cm strip of tape off the roll and bend one end over to form a handle. Stick this tape down on top of the L tape and gently rub it with your finger several times. This will form an "upper" type tape. Label it "U."

d) Slowly pull the L tape up (the U tape will be lifted along with it). Without separating the U and L tapes, hang them from the desk and gently rub both with your fingers.

e) Rapidly separate the U and L tapes. Minimize contact between the tape and any surrounding objects. Each can be suspended by one end from the underside to the desk for later use.