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Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 261 8 5.1 Static Electric Charges Warm Up Place meter stick on watch glass. Rub the inflated balloon on the hair and bring it close to a meter stick. Note the result. Describe and identify the reason for what you notice. Attraction and deterrence forces If your hair is dry and you comb it fast, your comb will attract not only your hair, but also bits of dust, paper or thread. The comb is probably made of plastic, but different types of material will produce the same effect. Already 600 m.c., the Greeks observed the force of amber when it was rubbed with a cloth. Amber is fossilized resin from trees that Greeks use for decoration and trading. Of course, magnets are also leveraging power, but they only attract some metal elements such as iron, nickel and cobalt, and some of their alloys. Amber, if rubbed with a cloth, will attract small pieces just about something. In the late 1500s, Englishman Dr. William Gilbert was curious about this interesting property of amber, and he did many experiments with it and other materials. Gilbert discovered that many materials, if rubbed with some fabrics, could be electrified. Words like electrified, electricity, electrons, and electronics come from the Greek word amber, which was electron. In the early 1700s, Charles du Fay, a French scientist, was probably the first person to figure out that there were two types of electricity. He pointed out that if two glass rods were rubbed with silk and brought to each other side by side, they would fend off each other. Repel means to push back. Two amber bars rubbed with fur also repel each other. However, if an electrified amber bar was brought closer to an electrified glass rod, the two bars could tie each other. Du Fay correctly concludes that there must be two types of electricity. Later in the 1700s, Benjamin Franklin named this positive electricity and negative electricity. By convention, a glass rod rubbed with silk is said to be a positive charge. The amber rod rubbed with wool or fur has a negative charge. In classroom experiments, a good way to get a positive fee is to rub the acetate plastic strip with cotton. A negative charge can be easily obtained by rubbing a strip of vinyl plastic with wool or fur (Figure 5.1.1). Chapter 262 5 Electrostatic project Edvantage Interactive 2013 ISBN 9 Image Two charged acetate plastic strips (+), loosely hanging from the support rod, repel each other. Two charged strips of vinyl ( ) also repel each other. However, a pay acetate strip will attract a pay vinyl strip. Since electrical charges for electrified items do not move, they are called static charges or Electricity. Static shall be stationary or stationary. Charged object will attract any neutral body. A neutral body is one for free. It will also attract the otherwise charged body, but it will repel another body to do the same charge. Authorities with the same charge to repel each other. Bodies with opposing accusations attract each other. A neutral body attracts either a positively charged body or a negatively charged body. Elementary Atomic Structure Image of a simple planetary model of atoms John Dalton's famous atomic theory assumes that the whole issue consists of inseparable particles. A very important experiment by Ernest Rutherford showed that the atom actually had some internal structure on it. He could show that the atom had a core that concentrated a positive charge. Since the atom as a whole is neutral, it must be negatively charged the substance should somehow be distributed through the nucleus. Negatively charged particles were first identified by English physicist JJ Thomson. They were later called electrons. A simplistic view of the atom, as pictured in rutherford planetary model shows the core of the atom with its positive charge, surrounded by negatively charged electrons. Positively charged particles in the nucleus are protons. The picture also shows neutrons, but they were not discovered until an English physicist named James Chadwick, a modern-day Rutherford, added this particle to the list of subatomic particles. Neutrons carry no electrical charge, and their mass is only slightly higher than the proton. Electrons are much less massive than protons or neutrons. The mass of the protons is kg, which is 1836 times the mass of the electron. The smallest atom is a hydrogen atom. This is the simplest possible core of one proton. The radius of the nucleus is approximately m compared to the hydrogen atom's radius in general, which is approximately m. Rutherford thought that the hydrogen core could be a basic unit for a positive charge. He was the first to use the label proton hydrogen core. The normal position of the atom is neutral. However, atoms can gain or lose electrons, in which case they become electrically charged atoms called ions. Since protons are safely locked away in the nucleus of the atom, only electrons are transferred from one body to another during the electrification of a normal object. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 263 10 Object electrification Image shows what happens when a vinyl plastic strip is rubbed on wool. Vinyl has a stronger affinity for electrons than wool. When vinyl contacts wool, some electrons leave the wool and go to the surface of the vinyl. It leaves vinyl with excess electrons, so it has a negative charge. Wool, lost electrons, is a positive curse. Image Charging a vinyl rod with wool: vinyl becomes negatively charged and the wool becomes positively charged. Similarly, if acetate plastic by rubbing with cotton, the cotton obtains electrons from acetate. Acetate becomes positively charged, while cotton becomes negatively charged. All experiments show that there is no electrical charge creation or destruction during electrification. All that happens is moving electrons from one body to another. Under the law of protection fees, the electric charge has never been established and has never been destroyed. Electric charging, such as pulse and total energy, is the amount saved. Electrostatic or triboelectric series Regardless of whether an object loses or acquires electrons when rubbed by another object, depends on how tightly the object holds on the electrons. The electrostatic or triboelectric series lists the various objects depending on how tightly they c their e-wires are (Figure 5.1.4). The higher the site on the list is, the stronger it is to hold on to the electrons. The lower the list of objects is, the weaker it is to hold because of the electrons. This means if we rub wool and amber together, the electrons will be moved from wool to amber. As a result, wool is positively charged and amber is negatively charged. Hold electrons tightly vinyl plastic wrap amber cotton paper silk fur wool glass hands + Hold electrons loosely Image Electrostatic or triboelectric series 264 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 11 Wires and Insulator wires are materials that allow charged particles to pass through them easily. Metals such as silver, copper, and aluminum are excellent conductors of electricity, but all metals perform to some extent. Atoms of metals are one or more external electrons that are very loosely connected to their nuclei so loosely attached that they are called free electrons. In Figure 5.1.5, the metal bar is supported by a plastic bucket. Plastic does not drive electricity. A negatively charged strip of vinyl is allowed to touch one end of a metal rod. When vinyl touches metal, some excess electrons are taken to the rod, so it becomes negatively charged as well. A negatively charged strip pushes away excess electrons to the far end of the metal rod. Initially neutral metal sphere, which hangs from the silk string, attracts a charged rod. When the sphere touches a negatively charged rod, some of the excess electrons are taken to the sphere. Since the sphere now has the same charge as the rod, it is pushed from the rod. Figure Electrons move from vinyl strip to metal rod and to ball. Now both the rod and the sphere are too electrons. If the vinyl strip is taken away, the rod and sphere will retain its negative charge and the sphere will remain in its repelled position. On a dry day, it can stay there for many hours. If the metal bar is replaced by a glass or plastic rod of similar dimensions, the metal ball does not move. This is because glass and plastic are insulators. Isolori are materials that the flow of particles through them. Examples of good insulators are plastic, amber, porcelain, various textiles, sica, sulfur and asbestos. Carbon form diamond is an excellent but very expensive insulator. Carbon in the form of graphite is a good conductor. Non-metals, such as silicon and selenium, find many applications in transistors and computer chips due to their semiconductor behaviour. It is easy to place a static charge on the insulator, because electrons are transferred only when two objects come into contact. When overcharges go up at some point on the insulator, the fee won't flow away so it stays static. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 265 12 Charging with a guide Electroscope is a device designed to detect excessive electrical charges. In Figure 5.1.6, the strip of positively charged acetate is sufficiently close to touch the electrical set neutral, with metal-salted. When they touch, free electrons on the surface of the conducting sphere will be tied to positively charged acetate plastic. Acetate will get some electrons, but its total fee will remain mostly positive. However, the sphere now has a positive fee, so it is re-pushed by a strip of acetate. We say that the sphere is accused of contact or directing. You could just as easily charge the sphere negatively by touching it with a charged vinyl strip. Illustration Charging Charging with induction objects can be charged without touching at all, in which case we call it induction. There are many ways to do this. The picture below shows one way. Two metal beads are on insulated stands and touch each other. A positively charged acetate strip is brought off two spheres, but it does not touch them. Free electrons from the right sphere are tied to the left sphere with a positive acetate strip. Now the right bullet is ejected away using an isolated support stand. Tests with an electroscope will show that the right ball is charged positively for induction. The left sphere is charged negatively by induction. Induction charge image note that no fee has been created during this procedure. All that has happened is that some electrons have been moved from the right sphere to the left sphere. The total fee is still the same as the charge attempted before the induction. The net fee is still zero. 266 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 13 Investigation using the purpose of conduction and induction Experiment with two different ways to shine on an object part 1 Handling when you charge an object by touching it with another charged object, electrons are carried directly to it. In the process, you are charging with wires. procedural rules. Install two aluminum pop cabins on or Styrofoam cups, as shown in the figure Styrofoam is an excellent insulator, so it any static charges you place on the cabins from escaping to the bench. 2. Place a negative charge on one of the cans as follows: (a) Rub the vinyl strip with wool or fur. You can hear the crackling sound when the vinyl is being charged. Vinyl will have a negative fee for it. b) Rub the charged vinyl strips over one of the isolated pop booths. Excess electrons from vinyl will flow on the can, giving can be a negative charge. (c) Repeat the process several times to make sure there are many excess negative fees on the can. Image Styrofoam acts as an insulator. 3. Place a positive charge on the other hand, you can: (a) Rub the acetate strip with cotton or paper. This will make acetate positively charged, as electrons flow from acetate to cotton. b) Rub the acetate strip on the second foot. A positively charged acetate strip will attract electrons from the second metal pop can, making it can be positively charged. (c) Repeat this process several times to make sure that the second can have a lot of positive fees. 4. Do not touch the metal seduaries. Touching only their insulated styrofoam base, move the cabins against each other until they are about 3 cm apart. 5. Lower the graphite or pith ball between two opposing charged ladders. Write down what you see happening. 1. Question referred for a preliminary ruling What fee was (a) the first one can start? b) the second can start? (c) graphite ball before it was lowered between legs? 2. Explain what happened to the graphite or pith ball during the experiment. Describe what happened to the electrons going to and from the three objects involved 3. Why does the action eventually stop? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 267 Part 14 Part 2 Induction Charging Imagine that you only have a negatively charged strip, but you want to place a positive charge on another object. If you touch another object with a negatively charged strip, you charge it for negative driving. However, if you use the induction method, you can give it a fee, which is the opposite of charging for the charging authority. procedural rules. Place a pop can on or styrofoam cup. 2. Charge the vinyl strip negatively. 3. Bring charged vinyl strips around and parallel pop can, but don't let the vinyl strip touch the can. 4. Briefly touch the cane with your finger, and then remove it and the vinyl strip completely. What do you think the fee is for can? Repeat steps 2 to 4 until the same result can be obtained three times in a row. 5. Arrange the procedure to check for yourself whether the fee per foot is positive, negative or neutral. 1. Question referred for a preliminary ruling Before you set your finger off the can, (a) what charge was on the vinyl strip? b) What fee was the side can at the vinyl strip? c) what fee was on the other side can? 2. Your finger may carry electrons on or from your body. In this experiment, were electrons taken to the can of the body or from can your body? 3. (a) What was the final fee per can? b) Was this fee made from a strip of vinyl? c) How can I get this fee? 268 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 15 5.1 Review Questions 1. What are the similarities and differences between the properties of electron and proton? 4. Draw a series of diagrams to show how an object can take a positive charge using only a negatively charged vinyl strip. 2. Describe the difference between a positive charge and a negative charge in terms of electrons. 3. Draw a diagram to show how an object can take a negative charge using only a negatively charged vinyl strip. 5. Why do clothes sometimes be static on them as soon as they come out of the clothes dryer? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 269 16 6. What will be the cost of a silk scarf if it is rubbed with glass? With plastic wrap? 8. What would happen if the vinyl strip in the picture was replaced by a positively charged acetate strip? Why? 7. A charged rod is brought to a pile of tiny plastic areas. The spheres are attracted by a charged rod and then fly off the rod. Why is this happening? 9. Outline the method by which you can determine for sure whether to charge for your comb after comb your hair is positive or negative. 270 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 17 5.2 Electric Force Warm Up You have to pay acetate strips and some confetti. How could you use these two pieces of equipment to prove which force is a stronger gravitational force or electric force? Charles Coulomb When you observe two objects that are tied or pushed due to electrostatic charge, you notice the non-comming forces in action. Both objects are exposed to each other without touching. The force of one inserant body can be measured. The force was originally determined by the French scientist Charles Coomb ( ). He used an apparatus similar to the Henry Cavendish gravitational force apparatus to work the relationship between these variables: strength, distance and amount of charge. The following illustration shows a setting similar to that used by Coulomb. Image Coulomb uses apparatus like this to study the relationship between variables in strength, distance, and quantity charge. In Coulomb's apparatus, the torque caused by the reeject of two similarly charged spheres caused the length of the vertical wire to twist over the angle. The twist amount was used to calculate the force of deterrence between the two charged areas. The apparatus is called the horse's balance. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 271 18 Coulomb's Law Coulomb could not directly assess the cost of the spheres. However, he found you can change the relative amount of the charge as follows: One sphere has an unknown charge Q for it, and the other identical sphere is zero charge. If you touch both of them together, both domains will charge 1 Q. It is assumed that the 2 excessive fees in the original sphere will be divided equally by the second, identical sphere. This additional fee distribution can be repeated several times to get spheres with a charge of 1 4 Q, 1 Q and so on. 8 The experiments between Coulomb and Others led to the conclusion that the force of attraction or abstinence between the two-point charges depends directly on the excess fee product on the authorities and inversely from the distance square between the two points. It is called the Coulomb Law and is written symbolically as follows: Q1Q 2 F = constant, or 2 r Q Q F = k r The volume of the proportionality constant k depends on the units used to measure the excess fee. If the unit of measure is a simple charge (as per electron or one proton), q would be measured as simple charges, and Q Q constant k F = k is the value r k = N m 2 /(elem. charge) 2 If the unit of measurement for excess charge is coulomb (named charles Coulomb), then Q will be measured coulombs (C) and constant k = N m 2 /C 2 Value k was developed after Coulomb's time. At the time he did his experiments, there were still no units for the quantity of fees. When scientists decided on an appropriate measuring unit charge, they named it after Coulomb. Coulomb's wording of the legislation mentions indications of accusations. The cob's legislation applies to very small fee institutions. If the charging authorities are large in relation to the distance between them, it is difficult to know what value r use. If the bodies have the same spheres, over which the fee is evenly distributed, then you can use the distance between their centers. If the two large, which control spheres, approach each other, the forces between the projectiles will cause excessive charging to be rearranged in spheres so that the toll centers cannot coincide with the mass centers. Coulomb and elementary fee It is now known that coulomb fees are equal to the amount of charge for electrons (if the fee is negative) or to the same number of protons (if the fee is positive). Fee per electron or one proton, called elementary charge, is 1 elementary charge (e) = x /C = C 272 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 19 Sample Problem Pendant's Law What force would be done with a 1.00 C positive charge per 1.00 C negative charge, which is 1.00 m away? What to think about 1. The two charges are separated by distance. This is Coulomb's rights issue. 2. Find each charge and distance and remember to follow the sign. 3. Resolve. 4. As you can see, C charges attract 1.00 C charge 1 m away with a force of nearly 10 billion newtons! Coulomb actually has a very high fee. How to do F = k Q 1 Q 2 2 r (Nm / C) (1,00 C) (1,00 C) F = (1,00 m) 2 F = N Practice Problems Coulomb s Law 1. A small metal ball with μc (micro-colours) are annexed to other metal ball charges at 2,10 μc. The distance between the two spheres shall be 3,7 cm. Find the amount of one charge force that acts on the other. Is it the force of attraction or deterrence? 2. What is the distance between two C and C charges experiencing the N force? 3. The push-back force between two identically charged small spheres shall be 4,00 N if they are 0,25 m apart. What is the charge in each area? Give your answer to microcoulombs (μc). (1 μc = 10 6 C) Use k = Nm 2 /C 2. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 273 20 Electrical Forces Due to multiple point charges If more than two charges are in the same area, the force of any of the charges can be calculated with the vector adding forces to it with one of the others. Remember that electrical power is a vector and adding vectors means both size and direction. Sample Problem 5.2.2(a) Three Collinear Charges Three tiny spheres are inged in a row, as shown in figure 1 and the third sphere is 4.00 cm apart and is charge Q=C and Q C=C. A negatively charged sphere is placed between two positive charges. The cost for this sphere is Q B = C. What is the net force on the negative sphere? Number Three collinear charge What to think about 1. The cost of sphere B is negative and the cost of the A-ball is positive. This means that the strength between the two fees is attractive. The same force between ball B and C. For this problem, the right will be positive. 2. Determine the net force in area b by adding two force vectors. How to do number F net = F C to B + F A to B QCQ B Q AQ B F =k +k 2 2 r r Nm / C (C) F = (0,20 m) (0,20 m) Nm / C (C) (C) + (0,20 m) (0,20 m) 3. The net force in area b shall be 0,25 N to the right. F = N + (0,99 N) = 0,25 N 274 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 21 Sample problem 5.2.2 2(b) Three payments in a triangle Three small spheres with identical charges +5,0 μc are located at the corners of an equivised triangle with edges 0,20 m long. What is the net force in any of the charged spheres? What to think about 1. The net force per payment will be the sum of the two repellent force vectors generated by two other identical charges. How to do this Let the three charges are A, B, and C. Figure shows their location on the triangle, and vectors representing the forces acting on A with projectiles B and C. 2. First, calculate the force generated by charging charged c Note A: The k value of the kulombu constant for this problem is rounded to Nm 2 /C 2.3. F C size on A and F B to A are the same, but their directions are not. Both forces are vectors, and they result in a vector and the result is by means of vector addition as shown in Figure F = F net = F C to A + F B to A figure Q F = k C 2 r Nm / C (C) (C) (C) F = (0,20 m) (0,20 m) F = 5,63 N F net Fnet FC to A sin 120 = 30 F C to A = sin 120 = (0,866) (5,63 N) = 9,80 N gr 30 (0,500) The direction of the grid force is on the line that crosses angle A, as shown in the figure you can solve the net force in several ways. You can use a scale diagram. Pythagorean theorem cannot be used precisely because the vector triangle is not a right-desolate triangle. You could divide it into two right angle triangles, drawing a line that bisecting 120 angles. The simplest solution is to use the sine law on the power triangle image Edvantage Interactive 2013 ISBN Chapter 5 Electrostatika PROJECT 275 22 Practice Problem Three charge Triangle 1. Small metal ball A with negative C charge is 3,00 cm to the right of another similar Sphere B with a positive C charge. The third sphere with a positive C charge shall be 1,50 cm directly above the second charge, as shown in figure (a) Calculate the net force of the (a) ball. b) Calculate net force b for area B) Calculate net force c 276 in field 5 Electrostatic substance PROJECT Edvantage Interactive 2013 ISBN 23 Investigation Coulomb's Law Purpose To investigate how the force between two electrically charged bullets varies depending on the distance between two spheres Introduction Direct force measurement generated by two charged spheres to each other is complex, but an indirect method can be used to compare forces at different distances. Figure 5.2.6 (a) shows a small graphite-coated ball mounted on an insulating stand. This sphere is charged with touching it with a charged strip of acetate. The acetate strip also collects a movable suspended ball. For the charges imposed on bullets (Q A and Q B), the duties imposed on the whole experiment should remain unchanged. Figure 5.2.6(a)r is the distance between the ball centres and d is the displacement of the moving ball from its initial position. Figure 5.2.6 shows three forces acting on the moving ball when they are pushed back by a similarly charged fixed ball. Vectors, representing gravitational forces, electrical forces and tension in a series, form a rightangled triangle. It should be noted that this force triangle is similar to the displacement triangle in Figure 5.2.6(a). As the triangles are similar, F E mg = d L Therefore, mg F L d E = Since m, g and L are constant during the experiment, we can write that F E = constant d or F E d Since F E is proportional d, we can use d as a measure of electrical force between two torched bullets at different distances r. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 277 24 Procedure 1. Install the equipment for this experiment on stage overhead projector. Project images from both spheres to the screen or on the board. Mark the position of the stopped ball before charging the balls. 2. Charge both spheres in contact with a rechargeable acetate strip. Perform several practices, bringing the installed sphere closer to the moving sphere and recording the at the same time. (If a graph grid is projected on the screen, measurements can be made in arbitrary grid units.) Practice is important. You have to take your measurements very quickly, especially if the humidity is high, because charging can leak from spheres to air. Note: The values on the r and d screen will be greater than the true values, but the projector increases both quantities by the same amount. 3. Once you have quickly mastered the r and d measurement techniques, conduct the experiment and record your data in the table. Try to get at least five readings. 4. Plot d to r. Check your form and make a reasonable guess about the nature of the relationship that exists between d and r. Sketch the second schedule d to r n, where n is the exponent you think will most likely produce a linear schedule. 1. Question referred for a preliminary ruling What relationship does your schedule suggest could exist between the electrical power of F E (which is proportional to d) and the separation distance r? 2. Thorough experiments by Charles Coulomb led to his conclusion that the electrical power between the two points of charge (very tiny charged bodies) ranged in the form of an inverted square separation between the point of charge. Ideally, schedule F E (or d) versus r 2 should be straight. Discuss the sources of errors in the experiment, which may deviate from the ideal result. 278 Chapter 5 Electrostatics PROJECT Edvantage Interactive 2013 ISBN 25 5.2 Overview questions When calculating your answers use the following figures: k = Nm 2 /C 2 1 elementary charge = C 1 C = elementary costs 1. What will happen to the force between two charges Q 1 and Q 2 separated by a distance r if: a) one of the charges has doubled? (b) the two charges are doubled? 3. What is the force of the push-back between two structures carrying 6,0 μc charge and separated by 1,0 μm? 4. What is the power of the binding between proton and electron hydrogen atoms when they are m apart? (c) the distance has doubled? (d) the distance has tripled? 5. The mass of one electron shall be kg. How many coulombs charge would be there for 1 kg of electrons? How much force does this charge act on another 1 kg of electrons, which are 0.6 miles away? (This is a strictly imaginary situation!) e) both charges have doubled and the separation distance has doubled? (f) the two charges are doubled and the separation distance is halved? 2. What force should a positive charge be applied to a 1,00 μc positive projectile at a distance of 1,00 μc? 6. Two small beads are located at a distance of 0.50 m from each other. Both have the same fee for them. If the scary force is 5,0 N, what is on the ball in the chest, μc? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 279 26 7. Three charged objects are located in the corners of an e-edge triangle with edges 1.0 m long. Two of the objects are 5.0 μc each. The third object gives a fee of 5.0 μc. How the resulting force acting on an object of 5,0 μc? Let's say all three objects are very small. 9. Discuss whether you think gravity could play a major role in holding atoms together. See the results of question 8. Calculate the gravitational force between the proton and electron m interval. Compare this force with the electrical force calculated in question Imagine you could insert 1 g of electrons at a distance of 1.0 m from another 1 g of electrons. (a) Calculate (i) the electrical force that will be repelled between the two charges. 10. Two protons resusems the other with a force of 1.0 piconewton (10 12 N). How far apart are the protons? (ii) the gravitational force of attraction between them. (iii) the ratio of electrical force to gravity. (b) Discuss the practical aspects of this imaginary situation. Chapter 280 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 27 5.3 Electric Strength Field Warm Up lit match is built at Van de Graaff generator. When the game gets close to charging the dome, it goes out. Why do you think this is happening? What is a field? Scientists use scientific models to describe naturally occurring situations that are difficult to observe. One of the first models you probably encountered at school was the solar system. The planets were represented by the scale and order of the Sun. Although not exactly correct, it gave you a system to understand the structure and overall functioning of the solar system. A force field is a model that provides a basis for understanding how forces are transferred from one object to another in a blank space. In physics, a field is a region of space in which a specified quantity has a certain value at each point. Gravity is an example of a force field. Remember that the strength of the gravitational field, g, is defined by F g = due to an array of bodies such as Earth, where both g and F are vectors. m G value varies by moving the test mass m away from Earth. In fact, g varies inversely as the square distance between m and the Earth's center mass. Representation of electrical fields The electric field is the region of space in which a charged object is triggered by force. To visualize the electric field, we use power lines to create a field vector chart. A field vector chart draws vectors that show the direction of the field and its size at different distances from fixed charging. The vector direction is the direction in which the force tends to push a positive test fee in this field region. The test fee is so small charging that it does not affect the source charge and does not change its electrical field. The following illustration shows a field next to a fixed positive fee. Image Field around a positive test charge Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 281 28 The idea of an electric field arose with Michael Faraday ( ), but he used another way to represent the field. He used power lines that showed the direction in which a positive test tend to move when placed anywhere in the area. The figure shows the power lines around: (a) a positive box is fixed and (b) a negative set of negatives. Figure (b) The force line around (a) a fixed positive charge and (b) a fixed negative charge indicator shall show (a) two inversely charged bodies and (b) two similarly charged bodies both positive. (a) Two pre-charged enclosures and (b) two similarly charged enclosures If two parallel metal plates are as in contrast to the power supply, a single electric field is created between the plates as shown in figure (b), a uniform electrical field 282 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 29 The field characteristics of electric lines are formed To compile the characteristics of electric lines, the field characteristics of the fields are : 1. Field lines indicate the direction of the electric field. 2. The field lines shall be drawn in such a way that the electrical field size is proportional to the number of lines drawn. The closer the lines are, the stronger the field. 3. Electric field lines shall begin with positive charges and shall end with negative charges. The higher the amount of the charge, the higher the number of lines that come from or go to the charge. Electric Field Patterns Formed Celery Seeds Image shows photos of electric field patterns in several situations. The insulating liquid was placed in a container with various charged items, and the celery seeds were dispersed into the liquid. Celery seeds line themselves up in an electric field in such a way that they give a visual representation of the shape of an electric field. Note that power lines are encountered on positively charged objects and end with negative batteries. The lines do not cross each other and they always correspond to the surfaces of objects at right angles. If rows are lined, this means that the field becomes weaker. The line density indicates the relative strength of the field in the different regions of the field. (a) Power lines around one charged bar (b) Lines of force around two conversely chargeable bars (c) Lines of force between two similarly charged bars (d) Lines of force between two opposite charged plates Skaitlis.b. Power lines illustrated using celery seeds in liquid Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic SUBSTANCE PROJECT 283 30 Quick Check 1. Draw and draw a sketch of each field, which represents celery in the seed image Let's say the wire on the right is positive. (a b)(d) (d) 2. Draw an electric field and show the direction between two positively charged objects. 3. Vinyl strip is rubbed with fur and the glass strip is rubbed with wool. Draw an electric field that occurs when the two charged items are tied together and parallel to each other. Defining electric field We started this section discussing gravitational areas. Then we discovered that there are electric fields around the charge, just as there is a gravitational area around the masses. This and their interaction can be represented by electric field lines. We can also quantify the strength of these rows. Although the strength of the gravitational field is the force per unit of mass, the strength of the electric field E is the force per unit charge. An electric field is a power field that exists where electrical power acts on a charge. Remember that F is the force that acts on the test charge in an electric field. Electric field strength F E = Q The electric field strength is measured in newtons per coulomb (N/C). 284 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 31 Sample Problem Electric Field Strength Positive test charge C experience force N west. What is the electric field in the test charge position? What to think about 1. Determine what you know: a positive charge is an electric area. You know how much of a fee and force fee experience. 2. Determine the correct formula: you are looking for an electric field. 3. Add the known values and solve How to charge it (Q) = C Force (F) = N E F = Q N E = = C N 5 C Practice problems Electric field strength 1. What charge exists for a test charge that experiences the force of N in a place where the electric field intensity is N/C? 2. Positive C test box with a force of 0.45 N. What is the electrical field intensity at this point? 3. What force is added to the c charge when it is placed in an electric field with a strength of 60.0 N/C? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatika PROJECT 285 32 Volume Electric Field Around The Source Charge Volume of electric fields around the source charge at a particular point can be determined even if Coulomb's law is combined with electric field strength. Note that it is important to remember which charge is the source charge (Q 1) and what is the test fee (Q 2), as shown in the figure, the source charge is Q 1 and the test fee is Q 2. F kq1q 2 E = and F = then 2 Q2 r kq1q 2 2 E = r Q2 Q2 Q E = k1 2 r Test fee Q 2 shall be waived to consider only the source charge Q 1. What is the strength of an electric field at a distance of 0.75 m from the 90 μc charge? 2. Proton is responsible for C. What distance from proton would the volume of the electric field be in N/C? 3. Charging produces 35.0 N/C electrical field at a point 3.00 cm away from it. What is the amount of this fee? 286 Chapter 5 Electrostatic Project Edvantage Interactive 2013 ISBN 33 Multiple Charge Creating Electric Fields There are times when more than one charge raises an electric field. Because electric fields are vector quantities, the grid field is at any time the sum of the vector fields of all the costs that contribute to that field. The following example shows how to vector a supplement to determine the net electrical field. Sample Problem Multiple Charge and Electric Fields Two negatively charged spheres, A and B, are 30 cm apart and are C and C charge, as in figure What is the net electric field at point P, which is exactly in the middle between the two charges? Figure What to think about 1. Determine what you know: both payments have an electric field. The electric field Q A is facing to the right at point P. Electric field Q B is to the left. Since Q A is double the charge, the net field will be fine. Make the right positive. 2. Locate the electrical field at point P created by Q A, and then do the same for Q B How to do Figure E Q A Q = k r A N m ( )(C) 2 = C (0,15 m) 2 E Q B = N / C Q N m ( )(C) 2 B = k = C 2 r (0,15 m) 2 3. The electric fields are vector quantities, so use a vector supplement to add two electric fields to point P. 4. Collect. = N/C E = E + E Net at P Q Q A B = N/C N/C = N/C The net electric field is N/C to the right. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 287 34 Practice problems Multiple charge and electric fields 1. The figure shows a positive recharging point close to a lower (volume) negative charge. Circle the Roman numeral representing the region in which the electric field is equal to zero due to both payments. Draw field lines to support your response. Figure What is the electrical field of the network at point P between the two opposite charging areas in the figure? Figure What is the volume and direction of the electric field in the P point of the image? Figure 5 Electrostatic projects Project Edvantage Interactive 2013 ISBN 35 5.3 Review Questions 1. The electron carries a charge C. If the N force causes the electron to move up, what is the volume and direction of the electrical field? 5. Proton passing between parallel plates, m at a distance from each other experiencing an upward electrical force N, as shown below. What is the volume of an electric field between the plates? 2. Proton is responsible for C. If it is an electric area of endurance N/C, what force acts on the proton? 3. A positively charged ball weighing N shall be held in a vertical electrical field as shown in the diagram. If the electric field strength is N/C, what is the cost per sphere? 6. What is the volume and direction of the electrical fields at a distance of m from fixed charge C? +36 μc charging is 0.80 m from +108 μc charge. What is the volume and direction of the electric field point in the middle between the two charges? 4. The iron nucleus contains 26 protons. What is the direction and volume of the electric field m from the nucleus? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 289 36 8. What is the size of the electric field at point P below? 10. The net electric field size at the P chart is N/C. What is the amount of charge in Q 2? 9. What is the resulting electrical field strength in point E in diagram A? Assign both size and direction. 11. Proton mass is kg. At what speed does it accelerate the electrical field of endurance N/C? 290 5 Electrostatic project Edvantage Interactive 2013 ISBN 37 5.4 Electric potential energy, electrical potential, and electrical potential difference to warm up household electrical outlet usually has a voltage of around 110 V. Van de Graaff generator can be charging thousands of volts. Why the shock of the generator doesn't hurt a person, but the shock of the 110-V household outlet is doing? Electric potential energy in unified areas of previous science classes, you studied working energy to train. The theory indicates that working with an object equals the change in the object's energy. A common example of this is when you lift an object against the force of gravity, for example by lifting a book from the floor to your desk. The book has gained gravitational potential energy when you lift it or, expressed in another way, when you work on it. Working energy theory is written as: W=E p We can use gravity potential energy example as an analogy to explain what happens to potential energy charges in a single electrical field. Table using gravity to explain the potential energy of the Charge Gravity Electric Charge 1. The gravitational field near the earth's surface and the electric field between the two charged plates are homogeneous. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 291 38 Table using gravity to explain the potential energy charge (continuation) Electric Gravity Charge 2. The mass of the gravitational field shall have a force equal to mg. Positively charged particles experience the force of QE. 3. The work done with the object by moving it to distance h is equal to the change in potential energy. If the charge is transferred from the A plate to the B plate, the work carried out shall be QEd in relation to the A plate. This is the electrical potential energy charged when, at the plate B, in relation to the plate A.4, the electrical potential energy shall be charged to the plate in relation to the plate A.4. Letting go of the mass causes it to fall to the ground and all potential energy is converted into kinetic energy when it reaches the ground. Charging go means that it will be tied to the A plate. All electrical potential energy will be converted into kinetic energy when it reaches the A plate. The positive test interval in Figure Q shall have the potential energy of electricity E in position A. This is because work needs to be done to move the positive accusation against the anti-resusving force that exists between two similarly charged institutions. In position B, the electrical potential energy is E pb. Figure B, the positive charging charger has more potential energy than heading A.292 Chapter 5, electrostatic PROJECT Edvantage Interactive 2013 ISBN 39 Quick Check 1. Explain the energy changes that electrons are exposed to when it is moved to a negatively charged plate and then released. 2. Using the image below, explain for potential and kinetic energy how to accelerate charging through the electrical field as the mass slid down the hill. Image If the electrical field field 2 had doubled, how would the slope of the mountain change? What if the electric field was halved? Electric potential energy multi-charge Over single field Many electrostatic situations are not in a single field. Note a situation where a small positive test (Q 2) is in the area of higher positive charge (Q 1). This is an example of a two-charge system with a single field. Q 1 is located at a distance r from the test charge Q 2. The test charge is the electrical potential energy because of the force exposed by the electric field Q 1. If Q 1 and Q 2 have the same mark, the force is disgusting. When the charge has the opposite features, the force is attractive. When Q 2 is released, it moves away from the positive Q 1. In terms of energy, this means that it will begin to move and acquire kinetic energy at the expense of its original potential energy. And to return to their original state would require work for a fee that would increase your potential energy. Edvantage Interactive 2013 ISBN Division 5 Electrostatic projects PROJECT 293 40 Any potential energy should be indicated in relation to the reference location. When we calculated the potential energy of gravity in Table 5.4.1, we used the Earth's surface as zero potential energy. For electric charges that interact with each other, the reference point is taken as infinity, as the charging electric field drops to zero at an infinite distance. This allows us to calculate the electrical potential of the energy system at two charges compared to infinity. This gives the equation: Q1Q 2 Ep = k r If the charges have the same sign, their potential energy is positive. This means that positive potential energy is a disgusting force. If the charges have opposite signs, the potential energy is negative. This means that negative potential energy is an attractive force. The potential energy of the charge decreases as it moves away from another charge of the same sign (Figure 5.4.3) and increases as it moves away from another opposite mark charge. Image Changes in potential energy 294 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 41 Sample problem calculation Electric potential energy What is electric potential energy compared to the infinity of electron hydrogen atom, if the electron is m of proton? What to think about 1. Determine what you know. One box is an electron; the other is with hydrogen atom proton. 2. Select the correct equation. 3. Determine the nature of the question: it is a plug-in type question for you to resolve with certain values. 4. Summary. How to do Q 1 = C Q 2 = C r = m k = Nm 2 /C 2 E p =? E Q Q k r 1 2 p = (Nm /C)(C)(m E p = 11 E P = J 19 C) The potential energy is negative because there is an attractive force between the electron and the proton. If you wanted to ionize a hydrogen atom (remove your electron to infinity), you would need 4.6 x J energy to do so. Internship problems Electric potential energy 1. How much work is required to point a charge C from infinity to a point that is 3.0 m away from a positive point charge in C? 2. There are two charges in the picture. If there is twice as much charge per charge compared to another, is the potential for electricity energy both charging itself or different? Explain your answer. Image 2 Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic projects PROJECT 295 42 Practice problems when calculating electrical potential (continued) 3. How far apart are the two electrons, if the potential energy to one of the electrons from infinity is J? Summary Summary, when two charged objects interact, we can explain the interaction by describing the forces of each object in the system using the Coulomb Act (see section 5.2), or we can describe the potential energy associated with the interaction. The electric potential energy depends on the amount of electrical charge and the distance from the source charge. If two charges are separated by distance, the interaction-related electrical potential energy is: E Q Q k r 1 2 p = We define infinity as the point at which one charge potential energy is zero. Quick check For each of these situations explain what will happen to the possible energy in the test chest. 1. A positive test charge shall be moved from A to B.2. The positive test charge shall be moved from B to point A.3. The positive test charge shall be moved from A to B. 4. Positive test charge when moved from B to A. 296 Chapter 5 Electrostatika PROJECT Edvantage Interactive 2013 ISBN 43 Electric Potential It's all about location, location, location Consider two negative charges are directed to the negative charge plate. One charge is twice as much as coulombs as others. This means that at any given time, a higher fee will require twice as much work on it, and there will be twice as much potential energy as a lower charge as it moves to the plate. You can calculate the total energy required to move both charges into the system. Sometimes it will be more appropriate to determine the electrical potential of energy units charging in place rather than the electrical potential of energy in one or more charges. The electrical potential energy stored per unit charge is the amount of work required to move the unit charge to a point in the electrical field. This is also called electrical potential or voltage. Although electric potential energy depends on the charge for an object that faces an electric field, the electrical potential depends on the location. It shall be written as follows: E V = p Q, where V is the electrical potential or voltage measured in volts, E P is the electrical potential energy measured by the beams and Q is the charges measured in the beams. So, 1joule 1volt = 1coulomb Electrical potential is used to express the impact of the source's electrical field in terms of location of the electrical field. For example, look at the three charges shown in the figure charge is in an electric field location for their electrical potential is 20 J/C. The 2 C test fee is twice as much as the 1 C charge and four times as much as the 0.5 C charge. The higher charge should be twice and four times the potential energy of a particular location compared to the 1 C and 0.5 C charge. But the electrical potential of this site would be the same for all three charges. Figure Electrical potential for three different charges at the same location, instead of charging the amount, is the main, negative test fee would have a high electrical potential if there's a close negative source charge and lower electrical potential if held further. In this way, the electrical potential is the property of the charging location in the electric field, not the amount of the charge. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 297 44 Quick Check 1. The C charge is moved between two rechargeable parallel plates. This increases the potential energy charge J. What is the electrical potential difference between the two plates? 2. How much energy does the electron have if it has an electrical potential of 50.0 V? 3. What is the charge for a small bullet that has J's potential energy but is suspended between two charged parallel plates that have an electrical potential of 200 V? Electric Potential Single Point Charge We know that the potential energy stored between two points of charge Q 1 and Q 2 is given by Coulomb's law: Q F = k r We also know that the potential energy charge Q 2 at a distance of Q 1 has been found taking the area below F vs r graph between r and infinity. The result is: Q1Q 2 Ep = k r We can combine these two concepts with the definition of electrical potential in a single point charge rather than a single electrical field. Electrical potential V, which is the potential energy per unit charge relative to infinity, then Ep Q1 V = k Q r 2 Remember that both the electrical potential and electric field in case of infinity are zero. 298 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 45 Quick Check 1. Two charges are separated by distance d. If the distance between them has doubled, how does the potential energy of the system change? 2. What is the electrical potential for infinity at a distance of 0,90 m from point charge (a) +50 μc? b) 50 μc? Electric potential difference figure B, positive test charge will have more potential energy. Recall that positive test charge Q has electricity potential energy E in position A (Figure 5.4.6). It will have more electricity for energy if it is moved to position B, because work needs to be done to move the positive charge against the anti-deterrence force that exists between the two similarly charged authorities. In position B, the electric potential energy is E pb. E For test charge Q at A, VA = Q Epb When the charge Q is moved to B, VB = Q Dials the potential energy difference on the unit charge between two points A and B, possible difference, V AB or ΔV only. VaB = ΔV = V B+A 5.4.6 The possible difference between points A and B is equal to the work carried out by moving Q from A to B. The possible difference can be measured beams to coulomb (J/C), but this unit is usually called volt (V). Or, in general form, V AB W E E W = = = Q Q Q PB via AB E V = Q p The potential difference is commonly referred to as voltage and ΔV is measured in volts, ΔE p beams and Q with lots. The possible difference (V) between two points is defined as the amount of work required to move the positive charging unit from a point with less potential to a point with greater potential relative to an arbitrary reference point (e.g. positive plate shown in Figure 5.4.6). Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 299 46 Sample Problem Working with possible difference How much work needed to move the C positive charge between two points, where the possible difference is 12.0 V? What to think about 1. Determine what you know. 2. Select the correct equation. 3. Resolve with known values to find the work done to move the fee. How to do w = E V = 12,0 V Q = C V = E Q = W Q SO W = VQ W = (12,0 V) (C) W = J Practice problems working with the electrical potential difference 1. A small C charge is moved between two parallel plates from the V electrical potential to another V position. What is the possible difference between these two positions? 2 What energy is stored in a 9.0 V battery when total charging is transferred from one set of electrodes to another in C? 3. C charging is between two charged plates that are 2 cm apart. The paid experience is valid for N. What is the possible difference between the plates? Electron Volt Atoms have a very, very large amount of energy on the volume of the joul. A smaller unit of energy, electron volt (ev) is used to solve problems related to electrical potential in situations on an atomic or nuclear scale. One electron volt is defined as the amount of energy obtained with one electron when it moves through a possible difference of 1,0 V. Since the charge per electron is only C, and W=V Q, one electron volt is only J. 1 ev = J 300 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 47 Sample Problem Working with electron volts If a 750 V shock-tube (CRT) is used to accelerate electrons, how many electron volts of energy will be obtained with every electron? What to think about 1. Determine the assumptions of the issue. 2. List the information you know. 3. Select the correct equation. 4. Determine the type of question: this is a plug type issue so you can solve it with certain values to find how much kinetic energy electrons get. Remember to find your answer sjoles. How to do this to take all the work carried out by the electrical field is converted into kinetic energy electrons. This means that W = VQ and E K = W, where E K is kinetic energy. V = 750 V Q = 1 e E K = W = VQ E K = (750 V) (750 V) (1 e) = 750 ev To convert their beams: 750 ev = (750 ev) (J / eV) 750 ev = 1.2 x J Practice Problems Working with Electron Volts 1. At room temperature the molecule is 0,04 ev energy. What is it s joules? 2. The electron hitting the screen crt display is about ev. What is the possible difference in electrons being accelerated through? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 301 48 5.4 Review Questions 1. The two-charge system has a positive potential for energy. What does this mean for both charges? 6. As shown below, the C fee is initially 7.0 m from the fixed C fee. What is the minimum amount of work required to move the C charge 1.5 m closer? 2. Tiny plastic slug is in the middle between two metal plates that are m apart. When the battery is connected to the plates, the ball experiences electrical force N. How much work is needed to move the bear ball from one plate to another? 3. What are the changes in the potential energy particle charge Q = +4μc that is brought from a distance of 4r to a distance of 2r with particle charge Q? 7. How much potential energy for the electron hydrogen atom to lose if it fell against the nucleus from a distance m to a distance m? 4. How much work does it take to fetch +5.0 μc from an infinity point to +25 μc? 8. How much work is done on moving the proton from infinity to the distance from another proton? 5. What is the electrical potential energy of electrons (relative to infinity) if it is m away from proton? 9. The proton is pushed into an electric field where it has 5.0 V electrical potential. If three electrons are pushed at the same time in the same area, what is the electrical potential of these three electrons? 302 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 49 10. The following diagrams show an electric field with two points, 1 and 2 positioned in the field. Paragraph 1 is a positive test box. For each scheme, indicate: (i) in the case of work carried out with a charge when moving from heading 1 to position 2; (ii) in the highest heading 1 or 2; (iii) Where is the electrical potential, the largest position 1 or position What is the difference between electrical potential and electrical potential difference? 12. Two parallel plates separated by m and the possible difference between them shall be 120 V, as shown below. Point P is located in the middle between the plates. What is the possible difference between point P and one of the plates? 13. The electron has a speed m /s. What is the energy of electron ev? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic Project 303 50 5.5 Electric field and voltage Uniform field warm up in your groups, describe the difference between electrical field and electrical potential difference. Image of the uniform fields of electric field and voltage No if the test box is between the two plates, it shall have the same electric force. The test charge Q between two plates otherwise that has been charged, the distance d of each other (Figure 5.5.1) shall be taken into account. This test fee will experience the same electrical force F anywhere between the two plates, because the electric field E is equal anywhere between the plates. The Big Idea Physics issue on the next page provides evidence of this. You know that when the positive test fee Q is moved from the negatively charged plate to the positive charged plate, to the distance of the work W allocated to W = Fd. The symbol of the potential difference or voltage is V. Therefore, the strength of the electric field can be calculated if we know the possible difference and the distance between two charged plates. It is calculated as follows: V E = d Since the potential difference (voltage) dimensions are energy dimensions per unit charge, it can be measured in J/C. However, the volt (V) is the standard voltage unit. This means that the electric field intensity can be expressed in volts per meter (V/m) as well as in newtons on fashion (N/C). Dimensions, they are the same. V J /C Nm /C = 1 = 1 = 1 m m N C 304 Chapter 5 Electrostatics PROJECT Edvantage Interactive 2013 ISBN 51 Big Idea Physics problem Is the force at a large, evenly charged flat surface constant? Here is proof to answer the Big Idea Physics question described above. Consider a small test charge q, which is the distance d from a large flat plate on which the charging is evenly distributed. Look at the large plate from q through an imaginary rectangular cone, we can see the area of a large plane with the amount of charge Q on it (Figure 5.5.2). The test charge q shall now be moved twice further to a distance of 2d. What happens to the electrical force on the test charge? Image Looking at the plane again from a double distance through the same imaginary cone, we see four times the size of the plane, and therefore four times the size of the charge (4Q). At first instance q effective was F Qq = k d 2 (Coulomb's Law), (4Q) q Qq In the new position twice further, F = k = k (2d) 2 d 2 Since the test charging force q has not changed, there is no change in the electric field strength F/q. It can be shown that the strength of the electric field between two large parallel plane surfaces is the same anywhere between the plates. (The area near the edges is not homogeneous.) Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 305 52 Sample Problem Working with electric field calculations A piece of scientific equipment has two metal electrodes that form parallel plates. If the voltage between the plates is V and the distance between the plates is 5,00 mm, which is the electric field? What to think about 1. Specify what you know and what you are looking for. 2. Select the equation. How to do V = d = 5,00 mm = E = ? E = V d 3. Solve E V E = = m = E V/m Practice Problems When Working with Electric Field Calculations 1. Inkjet printer sprays load ink droplets on paper to create images. If the ink droplets are passing through between two plates with a potential V difference and the electric field is V/m, what is the distance between the plates? 2. Two opposite charged plates shall be separated at a distance of 2.45 mm. What voltage should they apply to create an electric field in N/C? Show that N/C is the same unit as the V/m. 306 Chapter 5 Electrostatic Project Edvantage Interactive 2013 ISBN 53 Application Of The Single Electric Fields Katod Ray Tube Katod-ray Tube (CRT) is a special type of vacuum tube in which the beam electron is produced, accelerated, targeted, redirected, and displayed on a fluorescent screen. The CRT is used in oscilloscopes, radars and older TVs and computer monitors. 5.5.1. During the investigation, you will use a miniature ooster to observe the effects of electrical fields on electron beams. Electron beam pledges Acquire a small AC voltage is applied to the filament electron gun in Figure 5.5.3, and the resulting current heats the filament to filament lamps. When the filament is glowing, the electrons boil off and form a charge cloud around it. In front of the filament is an electrode called grid. The grid is negatively charged, so the electrons are irresistible from it. The grid makes the electrons converge with the focal point as they pass through a hole in the grid. This crossing point acts as a point source for electrons. Electrons flow from the point source accelerated by the electric field applied between the grid and the anode. Anode is a positively charged electrode. Image How the electron beam is formed using an electron gun The voltage applied to the network can be changed by allowing more or less electrons through the aperture. Because it will differ from the intensity of the light that determines the brightness of the light, as shown on the CRT screen, the network control is called intensity control. As the beam is focused and accelerated electrons, leaving the grid opening is different. The focusing anode (A 1) acts as an electronic lens, creating light so that when it reaches the screen, it will appear as a tiny place. The anode of acceleration (A 2) accelerates the electrons horizontally (Figure 5.5.4). The possible difference (voltage) between filament and acceleration anode is quite high usually 500 V, 750 V or 1000 V class V model. The high voltage between the filament of the electron gun and the acceleration anode creates an electrical field that accelerates the electrons. Due to the electrical field E, the work is carried out electrons and their electrical potential energy is converted into kinetic energy E k. The electrical potential voltage V a is a measure of the electrical potential energy change per unit charge. If the potential energy is converted into kinetic energy of the electrons, V a Ek = Q 1 mv 2 Q 2, where V a is the acceleration voltage (between A 2 and the filament); m is one mass of electrons (kg); v is the maximum speed achieved by each electron; and Q is one electron case (C). Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 307 54 Image Focusing electron beam As the beam is redirected When the beam is accelerated by Va and up to speed v, it is made to move between two interconnected perpendicular thawing plate pairs (Figure 5.5.5). The Y plates are arranged to move the light up or down in the y direction. This pair of plates is marked Y 1 and Y 2. A second pair of plates are arranged to shift the electron beam in the x direction. These plates are indicated by X 1 and X 2. Figure Katod ray tube (CRT) with power supply (simplified) Notice that plates X 1 and X 2 have a low DC voltage V δ on them. Both Y 1 and Y 2 are connected to A 2, but only one of the X plates is connected to A 2. This means that the two Y plates are at the same voltage as the A 2, so the electron beam passing through the Y plates does not see any difference in potential and y plates will not be diverted. However, one of the X plates has a slightly different potential than the other X plate, as the X plates are δ deflection voltage V. (δ is the Greek letter delta.) 308 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 55 W The picture below shows an electron beam moving at a speed v through a parallel deflecting plate pair. Remember that the electric field between parallel plates is constant anywhere between the plates; therefore, the electrical force is also constant. Illustration A beam of electrons moving between two parallel plates With constant unbalanced force will accelerate the electrons at speed a (down in Figure 5.5.6). Although through the plates passes through the plates at a time t, the downward acceleration makes the light fall through the displacement y. The displacement of the electron beam while it is between the plates is determined by y = 1 2 at 2, but since then, therefore, since the electric field F a = m F y = 1 2 m t 2 E F = so F = EQ and its Q 1 EQ y = 2 m t 2 The specified electron beam accelerates with a certain accelerated voltage, 1, Q, m, 2 and t will remain unchanged and it can be assumed that y = constant. E, or that y E. Also, whereas E = V δ /d where d is the distance between the deflation plates and V δ is the deflationary voltage, so the deviation is proportional to the deviation voltage V δ.y V δ Note: the deviation you measure on the screen is not y. When the beam leaves the deflation plates, the electrons move in a straight line to the fluorescent screen. From the fact that you see deviations δ. Fortunately, it can be demonstrated that the screen deviation δ is directly proportional to the true deformation ranges in the plates.* Since δ is proportional to y and y is proportional to the V δ, so δ V d This means that the light deviation measured on the screen is the voltage measure applied to the deflecing plates. The toy ray tube (CRT) can therefore be used as a voltmeter. Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 309 56 *Shows that δ is proportional to Y Consider electrons flowing into deflecting plates at horizontal speeds v x (Figure 5.5.7). The electron moves the distance x = l, at time t. Time is related to distance and speed as follows: t = x/v x, so the time spent by the electron between the two plates is l/v x. Figure Electron beam deviation between the two plates Now take into account the vertical deviation of the electron when passing through the deforming plates. Since the electric field and therefore the force on the electron are the same, the acceleration is the same, and y = 1/2 2 = 1/2a [x 2 /v x 2]. This is the equation of parabola. To find the slope of the parabola at the moment when the electron reaches the A (where the deflecting plate ends), we need to use calculus: dy dx a x ax = 2 (1) = 2 v v v x X When the electron leaves A, it moves in a straight line to B, so its slope remains the same as the A. This means that the trajectory of the straight line of the electron can be extrapolated from the A plate from the plate from the plate. It creates two similar triangles, with a height of y and y. The deviations you actually see on the screen are y, and y = δ. in Figure 5.5.7, the deviation in the plates is y. Similar triangles tell us that δ y! Chapter 310 5 Electrostatic projects Project Edvantage Interactive 2013 ISBN 57 Quick Check 1. Crt, voltage V accelerates electrons from rest to high speed. Assuming that all the work done by the electric field is used to give the electron kinetic energy, 1 2 mv2, what speed do electrons achieve? (The electron box is C and one electron mass is kg.) What part of the speed of light (c = m /s) is it? 2. If accelerating voltage V was used to accelerate protons, what speed do they achieve? (m proton = kg) 3. The CRT shall be used at an acceleration voltage of 750 V to accelerate electrons before passing through the defective plates to which a deviation voltage of 50,0 V is applied. (a) What speed do electrons achieve? b) When electrons move through deflation plates separated at a distance of 2,0 cm, what is the resistance of the electric field between the plates? (c) What is the force that will direct electrons when they cross the plates? (d) To what extent will electrons accelerate when they cross (e) The length of the plates shall be 5,0 cm. How long will the electrons be between the plates? f) What is the deviation in the direction of electrons when they pass through the plates? (g) If the screen is 0.20 m behind the end of the deformation plates, what deviation (δ) you will see on the screen? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic PROJECT 311 58 Investigation Deflecting beam electrons Using Electric Field Part 1 Target How does deformation of beam electrons at a given speed depend on deflecting voltages applied to deflecting plates between which beam passes? procedural rules. The image is a schematic diagram of a CRT device similar to the one you will use in this operation. On the X-plates will δ variable deviation voltage V voltage. Add X 1, Y 1, and Y 2 with total binding position A 2. The following apparatus shall be used throughout part 1 with an δ acceleration voltage V a 500 V. b) Connect the second wire from the resistor string +50 V binding point to the other end of the resistor string. c Connect the cord from X 1 to the total base of the resistors (0 V). Lead from X 2 can now be connected to any point string resistors, so you can get a voltage of 0 V, 10 V, 20 V, 30 V, 40 V, (d) Use a voltmeter to check the exact values obtained at each of the terminals (resistor junctions) and to confirm that this arrangement gives a range of voltages that are from each other. Figure 5 Electrostatic projects Project Edvantage Interactive 2013 ISBN 59 3. Put a piece of masking tape on the screen crt, so you can note the state of the beam when different deflecting voltages are applied. Mark the position of the beam for each of the voltages used (0 V, 10 V, 20 V, 30 V, 40 V and 50 V, if the power supply voltage is in place). 4. The values δ V and values shall be δ V δ the δ the data table. 5. Prepare δ V δ. Conclude question 1. How does δ of deflationary voltage V δ? Type an equation for your schedule, including inclination in the appropriate units. 2. How does the deviation depend on the strength of the electric field between the plates? How does your answer stem from the results of this experiment? (Remember how E and V δ are related.) Part 2 Objective How does the electron beam deviation depend on the acceleration voltage when a constant deflection voltage is used? Instructor Note: See your CRT manual if these instructions on changing V a don't apply to the model your students have. procedural rules. Find the zero position of the light, as you did in part 1, and mark it on a fresh masking tape attached to the screen. in Part 1: 500 V and divorced from the defective voltage. This time, leave the deflationary voltage at a value of 50 V throughout Part 2. (You'll use zero deflecting voltage to find zero position, of course.) 2. Mark the position of the electron beam on the screen at an acceleration voltage of 500 V. Turn off the power supply. Reset the acceleration voltage to 750 V. Switch the CRT on again, redirect and measure the new deformation if necessary, when V a = 750 V. 3. Turn off the power supply. Change V a to 1000 V. Turn on the CRT, reorient and measure δ.4. Before analyzing your results, use a voltmeter to check the actual voltage at the three A 2 terminals. Measure the voltage between the filament and each of the A 2 terminals. These are more reliable values to use in V a than what you read on the apparatus. The labeled values are only an approximate voltage. 5. Tabulating results, then plot a graph δ (y-axis) vs. accelerating voltage V a (x axis). 6. Make an educated guess at the power of the law relationship that exists between δ and V, and a piece of graphics that will tell you what the value n is δ =k V n a. 7. To obtain the expression on the deviation plates v a. Keep in mind that y is proportional to δ. Start by the fact that the deviation in the plates is y = 1 2 at2. Use the fact that the time spent in the plates will be F Electron acceleration is = Eq m = m. mv x Also the acceleration required va = q v x. According to your derivation, how y (and δ) differ with V a? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 313 60 Final question 1 final questions. Write a simple equation relating to deformation (δ) and acceleration voltage (V a). Include a numeric value for the constant of proportionality (slope). 2. If V a were doubled and V δ been kept the same, what would happen to δ? 3. If V δ been doubled and V a remained unchanged, what would happen to δ? 4. If both V a and V were δ, what would happen to the δ? Challenge 1. (a) What happens if you apply a low (6.3 V) AC voltage to the x-plates in your CRT? (b) What if you apply ac voltage to Y plates and X-plates at the same time? (c) Read up on lissajous curves electronics book. Use a full-size osilloscope to display them. 314 Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 61 5.5 Review Questions 1. Two parallel plates are probably 120 V. The division between the two plates is 10 cm. Calculate the electric field between them. 4. Nichrome wire 30.0 cm long is connected by terminals 1.5 V in a dry cell. What is the volume and direction (relative to the terminals) of the electric field inside the wiring? 2. The two electrodes on the spark plugs have an electric field between them at 500 V/ m and are separated by m. What is the voltage between the two plates? 5. Two parallel defition plates in the ostilostoge 120 V. They are separated by a distance of 2.4 mm. (a) What is the strength of the electric field between the plates? 3. What is the distance between two plates with a voltage of 800 V and an electric field N/C? b) To what extent will the electron (mass in kg) accelerate when it enters the space between the plates? (The electron initially moves in the direction perpendicular to the field lines.) Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 315 62 6. Between two charged plates, balancing the gravity force downwards with the same size of electrical force upwards, holds a small mass of plastic spheres in kg. a) What is the amount of electrical force acting on the sphere? 7. Two parallel plates have a potential difference between 2000 V and are m at a distance from each other. The proton is released from the positive plate at the same time as the electron is rejected from the negative plate. Compare and describe their speed and kinetic energy as they strike the opposite plate. b) If the application voltage on the plates is 30,0 V and the plates are separated by a distance of 1,47 mm, what is the sum of the overcharge on the ball? 8. Subatomic, charged C particle is accelerated from rest through V voltage. If the final particle speed is m/s, what is the mass of the particles? c) If the upper plate is positively charged, is the bead charge positive or negative? 9. The resting position of the bracket shall be accelerated between two parallel plates with a possible difference of 600 V, as shown below. What is the maximum speed of protons? d) What kind of elementary charged particles are on the ball, and how many of these extra elementary particles are on the ball? 316 Chapter 5 Electrostatic projects Project Edvantage Interactive 2013 ISBN 63 10. In the diagram below, the charged Sphere C and kg mass are held in the middle of two charged plates and balanced by gravity and electrical forces. What is the voltage V suitable for these plates? 11. CRT, if the deviation on the screen is 2.4 cm, if the acceleration voltage is 480 V and the deflation voltage is 36 V. What deviation (δ) do you see on the screen if the acceleration voltage is 960 V and the deflecting voltage is 18 V? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 317 64 Chapter 5 Review of questions 1. Two equal charges Q shall be separated by a distance r. The aidy force between them is F. (a) What will be the force if both charges are doubled? 3. (a) A tiny plastic ball is in the middle between two metal plates at a distance of m. When the battery is connected to the plates, the ball experiences electrical force N. How much work is needed to move the bear ball from one plate to another? b) What will be the force if the fee remains in Q, but the distance between them is reduced to 1 2 r? b) If the ball charge is 0,20 µc, what is the battery voltage? c) What strength will it be charges are increased to 4Q, and the distance between them is reduced to 1 4 r? 4. What is the scary force between two alpha particles that are 1.0 mm apart? (The alpha particle is a helium ion, He 2+, so it carries more than two elementary positive charges.) 5. How far apart are the two protons if they repel each other by a force of 1.0 mn? 2. A negatively charged rod is brought to a suspended metal ball. The sphere is grounded by touching it with your finger. The finger and rod have now been removed. What will be the cost for the sphere, positive or negative? Describe what happened. 6. If the body with charge C experience a force of 1.0 N electric field, what is the strength of the electric field? 318 Chapter 5 Electrostatic projects PROJECT Edvantage Interactive 2013 ISBN 65 7. Proton is placed in the N/C electric intensity field. (Mass of protons = kg; proton projectile = C) 10. The defective voltage applied to crt plates is 50.0 V. The plates are 1.2 cm apart. (a) What is the strength of the electric field between the plates? b) What force will the field have on the electron passing between the plates? 8. What is the electrical field strength and direction in the middle between the 75 µc charge and the 25 µc charge if the charge is 2,0 m from each other? (c) At what speed and direction will the electron accelerate? (Electron mass = kg) 11. An acceleration voltage of 750 V produces screen deviations of 4,2 cm per CRT. If the deflecting voltage is maintained unchanged, but the acceleration voltage is increased to 1000 V, what will the deviation become? 9. The strength of the electric field between two plates, which is 3,0 cm apart, is N/C. What is the voltage between the plates? 12. If the acceleration voltage CRT is 500 V and the deflationary voltage is 15 V, the beam deviation on the screen shall be 1,2 cm. If the acceleration voltage is changed to 750 V and the deflecting voltage is changed to 45 V, what will the deviation be? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 319 66 13. How much work should be done to move a positive +2.0 µc projectile from infinity to a point 1.2 m from a positive point µc charge? 16. Two very small beads each charge 3.0 µc. They are 4.0 cm apart. What is the potential for infinity in point P? P is 3.0 cm from both charged solders as shown below. 14. What is the electrical potential for infinity m away from proton? 15. Two-point µc projectiles shall be separated at a distance of 1,0 m. If the force between them is F, what will be the force if 4,0 µc is removed from one point charge and transferred to the other point of charge? 17. Protons are accelerated by a possible difference of 6.0 MV (megavolti) and then carry head-on collisions with atomic nuclei with a charge of + 82 elementary charges. What is the closest distance approach between protons and nuclei? Let's say the kernels are stationary. 18. How much must do to make three protons from infinity to distance m from each other? 320 Chapter 5 Electrostatic project Edvantage Interactive 2013 ISBN 67 Chapter 5 Additional practice Answer questions 1 and 2 using the scheme below. 1. What is the direction of electric field B, located between a couple of opposite charged plates? 2. Where is the electrical field strength between the plates strongest and weakest? 3. What is the direction of electric field P due to the point charge in the Q 1 and Q 2 chart below? 7. An atom that carries an excessive C charge accelerates from rest with a possible difference of 750 V. It reaches a maximum speed of m/s. What is the mass of an atom? 8. What increases the power potential of energy when an alpha particle with C charge is imported from infinity to c fixed charging distance? 9. Calculate the electrostatic tightening force between a positive C charge and a negative C charge if they are at a distance of 0,30 m from each other. 10. When a charged object is accelerated with a possible difference of 500 V, its kinetic energy increases from J to J. What is the amount of the object charge? 11. How fast will the electron move if it is accelerated from resting, vacuum, with a possible difference of 200 V? 4. Which of these units is the measure of electric field strength? (a) N/A b J/C c N/A m (d) N/kg e V/m 5. The electric field strength 1.0 m from the point of charge is N/C. What will the electrical field strength be at a distance of 2.0 m from the same point charge? 12. Two parallel plates shall be 4,0 mm apart. If the possible difference between them is 200 V, what is the strength of the electric field between the plates? 13. The electron enters the space between two otherwise charged parallel plates as shown below. What is the volume and direction of electrostatic forces that operate on the electron when it is between two plates? 6. The electron beam in the totod beam shall be accelerated against the anode by accelerating the voltage of 100 V. After passing through the anode, the electrons are diverted as they pass between the two otherwise charged parallel deflecting plates. The deviation observed on the screen is δ. If the acceleration voltage is increased to 400 V, what deviations will be observed on the screen? Edvantage Interactive 2013 ISBN Chapter 5 Electrostatic project 321 68 14. Charging C in the diagram shown in q diagram shall be the opposing forces generated by 5,0 N and 11,0 N Q 1 and Q 2 respectively. What is the volume and direction of electric field strength in place q? 16. What is the electrical potential of an electron in relation to the infinity that is m from the hydrogen atom proton? 17. What is the electrical potential of P due to charges Q 1 and Q 2? 15. How much work should I do to move the charge Q 2 = C from A to B, as shown in the diagram below? The second charged object has a charge of Q 1 = C. Chapter 5 Electrostatic PROJECT Edvantage Interactive 2013 ISBN 69 Chapter 6 Electrical Circuits By the end of this chapter, you should be able to take the following actions: Apply oms law to various co-existing circuits Apply Kirchhoff's laws to various co-start circuits Properly use ammeters and voltmeters Solve a range of problems related to the current , resistance, electrical potential difference, electrical power, and efficiency By the end of this chapter , you should know what these key terms mean: ammeter ampere normal electrical current electrical current electrical power electrical power (EMF) equivalent resistance internal resistance parallel circuit resistance series circuits terminal voltage voltmeter Until the end of this chapter, you should be able to use and know when to use the following formulas : Q = V = IR P = IV Vterminal = ± There t I These high voltage transmission lines play an important role by transporting electricity to your home and school, where energy is used to power a range of electrical appliances, including hybrid vehicles. Edvantage Interactive 2013 ISBN Chapter 6 Electrical Circuit PROJECT 323 70 6.1 Current Events History Warm-up Your Teacher will give you a light source, energy source and wiring. How many different ways can you arrange these three items so that the light source continues? Draw each chain. Galvani's and Volta experiments Up to 200 years ago, the idea of producing a stable current of electricity and putting it into use was non-existent. The discovery of the way to create the flow of electrical charges was, in fact, accidental. In 1780, at the University of Bologna, italian professor of anatomy Luigi Galvani ( ) was a dissecting frog. First, he noticed that when a nearby static power generator made a spark while a metal knife was touching frog nerves, the frog's legs would jump because its muscles contracted! Galvani continued to look for the conditions that led to this behavior. During the investigation, Galvani discovered that when two different metal objects (such as a brass hook and iron strut) touched each other while touching frogs exposed to flesh, the same contraction of the frog's legs occurred. Galvani thought that the source of electricity was the frog itself, and he called the phenomenon of animal electricity. Another Italian scientist, physics professor Alessandro Volta ( ) of Pave university, who is going to test galvani animal electricity theory for himself. A long time ago, Volta discovered that the source of electricity was in contact with two different metals. The animal (frog) was accidental. If any two different metals are submerged in a conductive solution of acid, base, or salt, they will create an electric current. Volta was able to prove that some pairs of metals worked better than other couples. Of course, no ammeters or voltmeters were available these days to compare currents and voltages. One way Volta compared was to observe the reaction of muscle tissue in dead frogs. Neither Galvani nor Volta could explain their observations. (There is no truth to rumors that the frog leg jumped since 1780 was a year long.) Many years later, it was learned that the radio waves generated by the ignition generator caused a current of a metal scalpel that was penetrating the frog, even though the scalpel was some distance away from the generator! Volta finally invented the first practical electric battery. Zinc and silver discs, separated by paper pads soaked with salt water, acted as electrical cells. Stake one above the other, these elements became a battery that gave more power than one cell. 324 Chapter 6 Electrical CircuitS PROJECT Edvantage Interactive 2013 ISBN 71 Cells and Batteries There are many types of electrical cells that exist today. Usually, when you buy a battery in a store, you actually buy one cell. Strictly speaking, the battery consists of two or more cells connected together. The nine volt batteries used in portable radios, recorders, calculators and smoke alarms are true batteries. When you open a discarded 9 V battery, you'll see six small 1.5 V elements joined together, one after the other, called a series. The picture below shows one type of volta cell (named Volta). Two rods, called electrodes, are made of carbon and zinc, as in a traditional dry cell, but they are immersed in ammonium chloride solution (NH 4 Cl). In a real dry cell, paste containing NH 4 Cl, sawdust and other ingredients is used. The chemistry of the voltaic cells will be left in your chemistry courses. The reaction that happens, however, has consequences in removing electrons from the carbon electrode (making it positive) and adding them to zinc (making zinc negative). In a real dry cell, the outer body of the cell is made of zinc. Zinc is dissolved away because the cell is used and can eventually leak its contents. Image Voltaic cells There are many types of cells and batteries. Rechargeable batteries can use nickel and cadmium, molybdine and lithium, or lead and lead oxide (as in a standard car battery). There are many types of cells on the market today, but they all produce electric current when connected by a controlled road. Electromotive Force Carbon-Zinc in a dry cell, forces the resulting from the chemical reaction in the cell to drive the charge to the terminals, performing work to overcome the a resentful forces. Working on the charge increases their potential energy. The possible energy difference between terminals is 1,5 J for each separated charge. We say that the possible difference is 1.5 J/C, or 1.5 V. For a cell or battery that doesn't play current, the potential difference is its maximum value, called electromotic force (EMF). It is given a symbol ε. The dry cell EMF has a 1.5 V. Nickel-cadmium cell is usually marked at 1.2 V or 1.25 V, but barely nickel-cadmium battery will have an even higher EMF than its labelled rating. Lead storage batteries are emfs 2 V each. Six of these elements connected to the battery provide a total EMF 12 V. Edvantage Interactive 2013 ISBN Chapter 6 Electrical Circuit PROJECT 325 72 Electric current When the electrical charge flow, we say that there is a current. The current will persist as long as a continuous driving path is established to flow from the emf source and back to it, as shown in the figure Figure Electric charge flow as a current through the conductor, unless there is a break on the road. Electric current is defined as the amount of electrical charge that passes the point of the circuit in one second. If the amount of charge Q goes point in the circuit at time t, then the Q average current I through this point is I =. t The current could be perfectly logically measured in the culmination per second (C/s), but this unit is called amper (A) by André Ampère (a French physicist). 1 A = 1 C /s One ampere is the type of current that exists in the 100 W bulb lamp in your home. (100 W lamp in 110 V chain retracted approximately 0,9 A.) For electrons, 1 A = electrons/electrons in the current direction, André Ampère arbitrarily defined the direction of the current in order to move positive charges between two points where there are potential energy differences. In many simple chains, we now know it's negative payments (electrons) that actually move. For solid conductors, positive charges are blocked in atomic nuclei that are set in their location crystal. Loosely attached electrons can move through the conductor from the atom to the atom. However, in liquids and gases, the charge flow can consist of positively filled ions, as well as negatively filled ions and electrons. Throughout this book, we will use the usual current direction: the direction in which positive charges could move between two points, where there is a possible difference between the points. Drift Velocity How fast do electrons move the wire in a current like 1 A? When the switch is closed in the circuit, the current effect can be determined immediately throughout the circuit. This can lead you to conclude that electrical charge (usually electrons) travel at very high speeds through the circuit. Actually, it's not! You can calculate the 326 Chapter 6 Electrical Circuit PROJECT Edvantage Interactive 2013 ISBN 73 average drift speed electrons in a given set of conditions can be calculated. Within the length of the metal wire, there are many, many loosely attached electrons (sometimes called free electrons). These electrons move around a lot like molecules in a container of gas could move. Let's look at the movement of electrons in the silver wire. Silver is a great conductor. Let's say that each silver atom has one free electron in a piece of wire. When the wire is connected to the emf source, the possible difference (voltage) will cause the electrons to shift from the negative terminal source EMF to the positive terminal. This movement is superimposed on the accidental movement of the electron, which occurs all the time with or without the source of the EMF. The journey made by electrons from negative to positive terminal is not smooth (as it is, for example, crt vacuum). Electrons in metal wire collide with positive silver ions en route and put some of their kinetic energy into silver ions. The increased heat energy of silver ions will appear as a temperature rise silver conductor. Let's say the silver wire current in the picture is 1.0 A. Then there are electrons passing the observer every second. This is because 1.0 A = 1.0 C / s = 6.24 x e / s Image Calculating the average drifting rate of an electron through a silver wire To calculate the average drifting rate of an electron, we start by once again assuming that there is one free electron for each silver atom, a reasonable assumption, because the chemist tells us that silver usually makes up the ions with a charge of +1. All we need to know is how long the silver wire image would be silver atoms (and therefore free electrons). We can find this in three stages, as follows: 1. Silver mass required to have free electrons is mass = atoms 108 g mole = atoms mole g 2. The volume of silver wire required to release the electrons is 3 masses g volume = = cm 3 density g cm 3 Edvantage Interactive 2013 ISBN Chapter 6 Electrical circuitRY PROJECT 327 74 3. The radius of silver wire in the figure shall be 1,0 mm or 1,0 x 10 1 cm. Its crosssectional area is πr 2, so the length, l, can be found as follows: volume length, = = area (cm 2 cm) = cm Its length cm contains electrons, and this many electrons pass observer 1 s, the average drift speed out electrons is cm / s, or mm / s! This, of course, applies only to the conditions indicated. If the amount of current, the nature of the material conductor, or the dimensions of the conductor changes, then the drift speed will also change. When you switch on the switch to switch the lamp using the battery, changes in the electric field can travel at the speed of light, but the electrons themselves drift so slowly through the wire under the influence of the electric field. Representing electrical circuitry Image shows a simple electrical circuit. There is a power source or battery, a device to use electricity (such as a lamp), a switch or control, and wires to carry out energy. Illustration Simple electrical circuit Any circuit can be represented by a schematic scheme using a common set of symbols. The following table lists some of the most common symbols used to draw electrical circuits. You will need to know each of these symbols so you can draw electrical circuits. Table Common symbols used in diagrams 328 Chapter 6 Electrical circuitry PROJECT Edvantage Interactive 2013