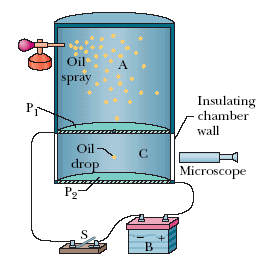
PHYS 301 Thompson & Millikan Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Thompson’s Cathode Ray Tube experiment
2. Watch the following video: <https://www.youtube.com/watch?v=Rb6MguN0Uj4>
3. Read the attached hand-out, pages 2-3.
4. Millikan’s Oil drop experiment

Watch the following video: <http://www.youtube.com/watch?v=2HhaQtvICe8>

1. In Millikan's experiment, an oil drop of radius 1.73 μm and density 0.859 g/cm3 is suspended in chamber C by means of an electric field of 0.293 × 105 N/C, applied using the battery B.   
   a. Define electric field.  
   b. Show the electric field in the chamber C.  
   c. Name the two forces that are acting on the oil drop.   
   d. Find the charge on the drop.



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| 28-4 | **Crossed Fields: Discovery of the Electron (HRW)** |
| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |

Both an electric field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif and a magnetic field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math002.gif can produce a force on a charged particle. When the two fields are perpendicular to each other, they are said to be *crossed fields*. Here we shall examine what happens to charged particles—namely, electrons—as they move through crossed fields. We use as our example the experiment that led to the discovery of the electron in 1897 by J. J. Thomson at Cambridge University.

Figure [28-7](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-fig-0007) shows a modern, simplified version of Thomson's experimental apparatus—a *cathode ray tube* (which is like the picture tube in an old type television set). Charged particles (which we now know as electrons) are emitted by a hot filament at the rear of the evacuated tube and are accelerated by an applied potential difference *ν*. After they pass through a slit in screen C, they form a narrow beam. They then pass through a region of crossed http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif and http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math002.gif fields, headed toward a fluorescent screen S, where they produce a spot of light (on a television screen the spot is part of the picture). The forces on the charged particles in the crossed-fields region can deflect them from the center of the screen. By controlling the magnitudes and directions of the fields, Thomson could thus control where the spot of light appeared on the screen. Recall that the force on a negatively charged particle due to an electric field is directed opposite the field. Thus, for the arrangement of Fig. [28-7](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-fig-0007), electrons are forced up the page by electric field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif and down the page by magnetic field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math002.gif; that is, the forces are *in opposition.* Thomson's procedure was equivalent to the following series of steps.

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| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |  | | --- | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | |  |  |  |  | | --- | --- | --- | --- | | |  | | --- | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/image_n/nt0008-y.gif | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | |  |  |  | | --- | --- | --- | | [Figure zoom](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-fig-0007) | **Figure 28-7** | A modern version of J. J. Thomson's apparatus for measuring the ratio of mass to charge for the electron. An electric field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif is established by connecting a battery across the deflecting-plate terminals. The magnetic field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math002.gif is set up by means of a current in a system of coils (not shown). The magnetic field shown is into the plane of the figure, as represented by the array of **X**s (which resemble the feathered ends of arrows). | | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif |

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| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |  |  | | --- | --- | | **1.** | Set *E* = 0 and *B* = 0 and note the position of the spot on screen S due to the undeflected beam. | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | | **2.** | Turn on http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif and measure the resulting beam deflection. | | http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | | | **3.** | Maintaining http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif, now turn on http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math002.gif and adjust its value until the beam returns to the undeflected position. (With the forces in opposition, they can be made to cancel.) | |

We discussed the deflection of a charged particle moving through an electric field http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math001.gif between two plates (step 2 here) in the sample problem in the preceding section. We found that the deflection of the particle at the far end of the plates is

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| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |

where *ν* is the particle's speed, *m* its mass, and *q* its charge, and *L* is the length of the plates. We can apply this same equation to the beam of electrons in Fig. [28-7](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-fig-0007); if need be, we can calculate the deflection by measuring the deflection of the beam on screen S and then working back to calculate the deflection *y* at the end of the plates. (Because the direction of the deflection is set by the sign of the particle's charge, Thomson was able to show that the particles that were lighting up his screen were negatively charged.)

When the two fields in Fig. [28-7](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-fig-0007) are adjusted so that the two deflecting forces cancel (step 3), we have from Eqs. [28-1](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-mdis-0001) and [28-3](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-mdis-0003)

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| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |

or

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| http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/math/math015.gif | (28-7) |
| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |

Thus, the crossed fields allow us to measure the speed of the charged particles passing through them. Substituting Eq. [28-7](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-mdis-0007) for *ν* in Eq. [28-6](http://edugen.wiley.com/edugen/courses/crs4957/halliday9118/halliday9088c28/halliday9118/halliday9088c28/halliday9088c28xlinks.xform?id=halliday9088c28-mdis-0006) and rearranging yield

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| http://edugen.wiley.com/edugen/courses/crs4957/common/art/pixel.gif | |

in which all quantities on the right can be measured. Thus, the crossed fields allow us to measure the ratio *m*/|*q*| of the particles moving through Thomson's apparatus.

Thomson claimed that these particles are found in all matter. He also claimed that they are lighter than the lightest known atom (hydrogen) by a factor of more than 1000. (The exact ratio proved later to be 1836.15.) His *m*/|*q*| measurement, coupled with the boldness of his two claims, is considered to be the “discovery of the electron.”