EDUCATIONAL TRANSFER PLAN ----- STUART BRIBER
MENTOR- DR. HARTMUT SADROZINSKI
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SANTA CRUZ INSTITUTE FOR PARTICLE PHYSICS, UC SANTA CRUZ

This summer I had the opportunity to work, along with fellow teacher Leo Florendo, on lab apparatus set up for physics students at the university. From this we have tried to adapt some of the experiments and demonstrations to equipment more commonly found in high schools. Following are some of these adaptations.

HIGH SCHOOL PHYSICS DEMONSTRATIONS AND LAB POSSIBILITIES:

1) PHOTO-ELECTRIC EFFECT: This famous experiment was first done in the late 1800’s and was made famous by Einstein’s interpretation of its results. The basic effect occurs when light strikes the surface of some metal. It has been found that the light energy will liberate a certain number of the metal’s electrons. The brighter the light, the more electrons are emitted. The puzzle for classical physics, which considered light to be only a wave, was that the kinetic energy the liberated electrons (referred to as the photoelectric current) did not depend on the light intensity, only on light frequency (color). If the wave model of light was correct, extra light intensity (larger waves) would give the electrons more kinetic energy after they were freed from the metal surface. Einstein proposed that light could be thought of as quanta, small particles or photons. The energy of the quanta only depended on the light frequency, a brighter light merely had more photons, but since any given electron in the metal could only interact with one photon, the energy it received was fixed. Increasing the light intensity only serves to increase the number of photon electron collisions and hence the current.

DEMONSTRATION: One purpose of this lab is to verify that different wavelengths of light do in fact eject electrons with different amounts of kinetic energy, a maximum energy associated with each wavelength. Further we can show that changing the light intensity at any given wavelength does affect the amount of photocurrent but not the energy of the electrons in the current. In the more expensive version of the demo, light from a mercury vapor lamp is shined through a diffraction grating such that specific wavelengths strike an electrode in a vacuum tube. The small current arriving at an adjacent electrode (anode) in the tube is measured by an electrometer. Typical currents were on the order of nanoamps. Simply by partially blocking the light beam with successive amounts of plastic wrap or other transparent material of uniform thickness is sufficient to show how the resulting photocurrent depends on intensity. To measure the kinetic energy of the electrons ejected from the metal, an opposing stopping voltage was established between the electrodes to oppose the flow of the photo current. When this measured voltage was raised sufficiently to completely stop the photocurrent, the KE of the electrons is effectively neutralized. The energy repelling the electrons (=Ve, V is the stopping voltage across the electrodes, and e is the charge of an electron). This measurement of stopping voltage is found to remain constant when the light intensity is varied. However, when different wavelengths from the light source are used to illuminate the metal electrode, it is generally found the necessary stopping voltage required increases as the wavelength of light is decreased.

PHOTO-ELECTRIC EFFECT -SHORT VERSION: Using only a leaf electroscope and an UV light source one can show the photoelectric effect qualitatively. First it is necessary to make sure the electroscope is totally dry, blow on it with a warm air source such as a hair dryer. Place an isolated piece of metal such a zinc in contact with the external contact of the scope. The metal must also be very clean and dry. Charge metal and the scope negatively (contact it with a rubber rod rubbed with fur). At this point the leaves of the electroscope should be repelling. Now shine the UV lamp on the piece of metal, the scope leaves will neutralize as the light ejects the excess electrons. You can show the effect is accelerated and the current increased by a change in light intensity (just hold the light at different distances from the electroscope).

An interesting way of showing features of the photoelectric effect in reverse is to take some form of vacuum tube in which the electrode ends are visible (accessible to photons) inside the tube. When one of the electrodes is illuminated with a light (such as a laser) a voltage can be detected between that electrode and another electrode in the tube that is not illuminated. Some of the electrons driven from the atoms on the illuminated electrode will migrate to the "dark" electrode to create this voltage. You will probably need a very high impedance voltmeter (electrometer) to measure this voltage. If you have the ability to increase or decrease the light intensity you should find that the time to establish the maximum voltage is affected but not the value of that maximum voltage. The actual value of the voltage maximum is instead a function of light frequency (color). Einstein was able to explain this by postulating that light was acting as particles whose energy was related to their wavelength/ frequency, rather than waves whose energy was a function of the intensity (amplitude). Increasing light intensity therefore increases the flux of light particles (photons) and hence the rate at which they strike and liberate electrons in the metal electrode, but the energy of the electrons themselves (and hence the maximum voltage they can build up between the electrode being illuminated and background) is not affected. Observed differences are in the range of millivolts, with higher voltages occurring at higher light frequencies. Only certain frequencies excite and free electrons so the photoelectric effect does not work with all colors of light.

LIGHT POLARIZING TOWER:

In this demonstration of birefringence and polarized light, a 4-foot long clear plastic pipe is filled with a saturated sugar solution. It is placed vertically on a standard is illuminated through its length with a high intensity white light lamp from below. Between the lamp and the bottom of the tube (which is sealed with a clear piece of acrylic plastic) is placed a piece of linear polarized film. Light entering the tube is therefore linearly polarized.

The light that scatters out the side of the tube is also polarized due to the scattering off the sugar molecules. The purpose of using sugar is due to its birefringence; i.e. it progressively twists the plane of polarization for the light traveling the length of the tube. The further the light travels up the tube, the greater the polarization plane of the light is rotated. This rotation angle depends not only on the path length of the incoming light but also on the wavelength of that light. Consequently, the light which is scattered out the sides of the tube is all of 1 wavelength at any given distance. The overall effect is for the visible colors of the rainbow to be scattered and visible over the length of the tube.

CAVENDISH EXPERIMENT to DETERMINE the GRAVITATIONAL CONSTANT

As a variation on the original setup of Cavendish's experiment to measure the universal constant of gravitation, this project involves hanging a weight on a spring inside a closed tube. Another mass can be brought close to the hanging mass from below. The slight change in spring length that results can be measured using an optical lever as was done in the original experiment. This system also allows an observation of the gravity from the sun and moon. The calculated force of the sun on a one Kg. mass is on the order of 1/100 N. The most critical element is to find a spring of sufficient sensitivity that is also strong enough to suspend the mass without permanent deformation.

Considerations for this project include:

- Enclosing the entire experiment in a transparent tube to exclude the effect of air currents.
- Making sure the laser used to create the optical lever is secure to a frame of reference that includes the tube.
- Keeping a stable temperature environment for the experiment.
- Being aware of the different times of day and the resulting change in tidal effects from the sun and moon.