Summer Placement - Outreach

H M Wakeling

8 June 2015

Abstract

This summer these outreach experiments were created.

1 Cloaking Device.

The aim of this task was to be able to demonstrate the possible manipulation of visible light to create a region of cloaking. This invisibility cloak can then be used for demonstrations in lectures and presentations.

1.1 The theory of a one directional invisibility cloak.

It is possible, through the manipulation of light, to create an invisibility cloak. Here we focus on the one directional cloak. The dimensions of the setup were calculated using equations [1]

$$t_1 = f_1 + f_2 \tag{1}$$

$$t_2 = 2f_2 \cdot \frac{(f_1 + f_2)}{(f_1 f_2)} \tag{2}$$

where t_1 is the distance between the first lens and the second (and the third lens and the fourth), t_2 is the distance between the second and third lens, f_1 is the focal length of the two outer lenses and f_2 is the focal length of the two inner lenses.

1.2 Creation of the one directional invisibility cloak.

Using Howell's method of Cloaking with Lenses [3] with four Fresnel lenses, each with a focal length of 310mm, an invisibility cloak was created. Using equations 1 and 2 the lens distances were found to be $t_1 = 620$ mm and $t_2 = 0$ mm. As fresnel lenses were used the image had high chromatic abberation, which severely lessened the effect of the cloaking device.

2 Coke Can Quantum Effects.

The aim of this task was to be able to demonstrate the photoelectric effect with the use of household objects. This would show educators that they're able to do this experiment with a low budget. Through use of second hand objects obtained through colleagues, the only purchased object of this experiment was the UV-C light source, which can be bough online for £5 - £20.

2.1 The theory of the photoelectric effect.

When light sources of the right frequency are shone on particular types of metal, an electric current may be detected. This is because a photon has a discrete value of energy, dependent on its frequency. When the energy of an incident photon is the right quantity, it transfers its energy to an electron that is close to the metal surface. For the electron, this gain in energy means it can escape the metal surface. If it has gained enough energy the electron can travel after its escape, creating an electric current, as shown in Figure 1.

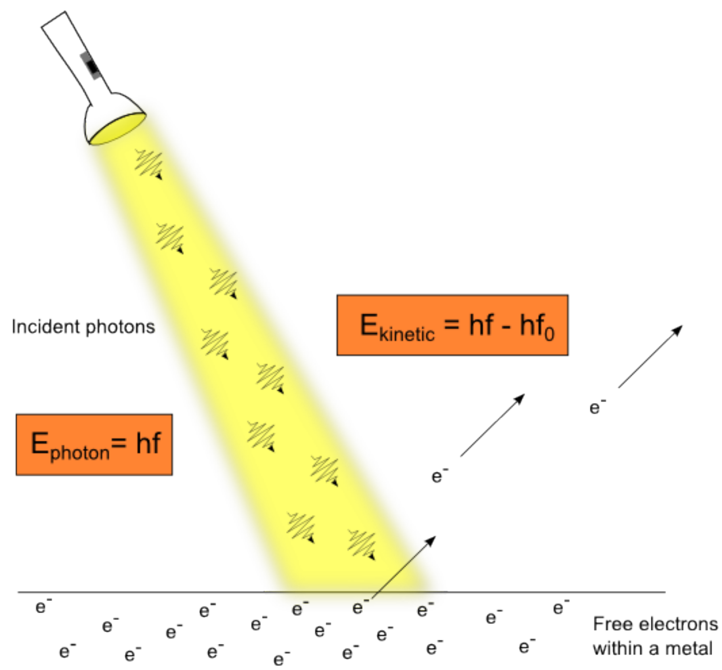

Figure 1: Diagram of the schematics of the photoelectric effect.

2.2 The setup of the experiment.

The effect can be shown using a polystyrene cup, tape, an aluminium can, copper wire, sandpaper, a balloon, long pieces of tinsel and a UV-C light wand source of wavelength 253.7nm constructed as in Figure 2.

2.3 Troubleshooting the experiment.

One problem stalled the completion of this demonstration as the photoelectric effect would not originally work. There were a few explored possibilities of the cause of this failure. The aluminium may have oxidised

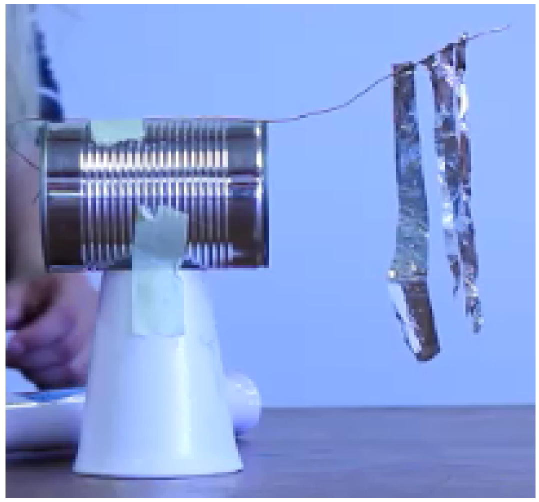

Figure 2: Photograph of the setup of the experiment.

or may still have a layer preventing the UV rays freeing the electrons. To combat this the paint layer was sanded off one side of the can, then before each attempt, this section was lightly re-sanded to remove any new oxidisation. The UV-C source may not be the wavelength stated in the manufacturing booklet, therefore the threshold frequency may not have been reached. In theory, the UV-C light source would cause the photoelectric effect for metals with a work function lower than

$$E_{UV} = \frac{hc}{\lambda} = \frac{6.64 \cdot 10^{-34} * 3 \cdot 10^{8}}{253.7 \cdot 10^{-9}} = 4.89eV \tag{3}$$

where E_{UV} is the energy of the photons of the UV source, h is Planck's constant, c is the speed of light in a vacuum, and λ is the wavelength of the UV source. Therefore, metals with a lower work function than this could be used. The material that the 'aluminium' can is made out of may be an alloy with a higher work function than expected. Instead of the can, other objects were used including; an aluminium slab, aluminium food foil sheet, a foil cake tin and a takeaway food container, but these also did not work. The photoelectric effect may have been happening so slowly that it's not visibly discharging. The solution in the end came from the way the electric charge was being created. The PVC tube being used would take the electrons away from the setup, not add them on. When an amber rod was used instead, the photoelectric effect took place as electrons were added to the setup as intended.

3 Creating a Cloud Chamber.

The aim of this task was to demonstrate to teachers that a Cloud Chamber could be created on a small budget.

3.1 Equipment

Fish tank
Foam (thick rectangle of dimentions 2 inches more than the fish tank)
Felt
Metal Sheet (should fit snugly on the top of the fish tank, so that it can be sealed there)
Black duct tape
Cardboard box (should fit around the foam)
Stapler
Silicon sealant
Dry Ice
Isopropyl Alcohol
(Dimensions may be altered, as long as the function of that object still obtains the same end.)

3.2 Theory behind a Cloud Chamber

The Isopropyl alcohol becomes a vapour and the chamber is saturated with it. A steep temperature gradient is created with the dry ice so that, as the vapour drops to the bottom of the chamber, it is supercooled. Vapour isn't usually vapour at supercooled temperatures, so it will be very easily condensed into liquid form. Cosmic rays will pass through the supercooled vapour and ionise it. The ionisation means that electrons are removed from the vapour atoms, leaving them positively charged. Now being positively charged, the ionised atoms attract other nearby atoms, which starts the condensation process. We are then able to view the path of the cosmic ray as a spindly, short lived line of droplets. By placing a very strong magnet against a side of the chamber, one may see particles bend when they're in the magnet's field. This is because these particles have a charge, so their paths are altered by the field.

3.3 Setup of the Cloud Chamber

Fit the foam into the bottom of the cardboard box, and cut away the box so that it is slightly higher than the foam that's inside it. This will be the part of the cloud chamber that contains the dry ice. The foam insulates the dry ice and will make the it last longer. Make sure the metal sheet is black on one side, either through blackening, black tape, or paint etc. This will allow for easier viewing of the particle paths. Roll or fold the felt so that it is a relatively thick piece of material, and secure using the stapler. Place the felt inside the fish tank, about 6 inches up from the open end of the tank, and seal it with silicon sealant to the edges of the tank. Whilst the sealant is out, ensure the edges of the tank are suitable to create an airtight environment. Soak the felt with the Isoproyl alcohol, then place the metal sheet on the open end of the fish tank, ensuring the black side is facing inside the tank. Now seal the sheet to the tank with the black duct tape, making sure it is airtight. Next place the dry ice into the foam. Turn over the fish tank, so that the metal sheet is now on the bottom, and place on top of the dry ice and foam.

After about 15 minutes, once the temperature gradient is sufficient, the vapour will be supercooled enough for one to start being able to observe the effects.

References

[1] Barnston D.Cloaking device uses ordinary lenses to hide objects across range of angles. *University of Rochester*. [Online]. Available from: http://www.rochester.edu/newscenter/watch-rochester-cloak-uses-ordinary-lenses-to-hide-objects-across-continuous-range-of-angl [Accessed 1st July 2015].

[2] Howell JC, Howell JB. Simple, broadband, optical spatial cloaking of very large objects. *arXiv.org*. [Online]. Available from: http://arxiv.org/pdf/1306.0863v3.pdf [Accessed 18th June 2015].

[3] Beehler A. Simple Photoelectric Effect. *University of Utah*. [Online]. Available from: http://www.physics.utah.edu/~beehler/newsletterdemos/SimplePhotoelectricEffect.pdf [Accessed 22th June 2015].