San Diego Mesa College
Physics 197 Laboratory Experiment
Title: Determination of Planck's Constant

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Date: ______________________________
Group Members: ______________________
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Objective: To demonstrate that the maximum energy of a photoelectron is independent of the intensity of the incident light, and to demonstrate that the maximum energy of the photoelectron is dependent upon the frequency of the incident light. You will also determine the value of Planck's constant and the work function of a particular surface.

Theory: Early experiments revealed that light incident on a metallic surface could cause the emission of electrons from the surface in a process called the photoelectric effect. Einstein proposed that the principle of quantization could explain this. By assuming that light was made up of a stream of particles he called photons, where each photon carried an amount of energy proportional to the frequency of the light.

$$E=hf$$

where h is a fundamental constant of nature called Planck's constant. In this model, the photon delivers all of its energy to an electron in the material. If the energy of the photon is sufficiently large, the electron is ejected from the surface with a maximum kinetic energy equal to the difference in the incoming photon energy and the amount of energy required to free it from the material. The amount of energy required to free it form the material is called the Work Function (Φ) The relationship may be summarized as follows:

$$E = hf = \Phi - K_{\max imum}$$

If the photon energy is less than the work function, then no photoelectrons may be generated. If the photon energy is exactly equal to the work function, the created photoelectrons will have zero kinetic energy. Finally, if the incident photon energy is greater than the work function, the photoelectrons will possess non-zero kinetic energy.At the heart of the matter is the difference between the wave model and the quantum model of light. In the wave model, an increase in the intensity of the light source will increase the kinetic energy of the photoelectron, since the amplitude of the wave will increase, so will the photoelectron energy. On the other hand, the quantum model postulates that only the frequency of the incident light is important in setting the kinetic energy of the photoelectron. Increasing the intensity should increase the *numbers* of photoelectrons, but not the energy of an individual photoelectron.

Since the electron is a charge particle, one can calculate the kinetic energy of a moving electron by measuring the change in potential energy required to bring it to rest. With a conservative force, the change in potential energy is the same as the change in the kinetic energy of object and so:

$$|qV| = \frac{1}{2}mv^2 = \Phi - hf$$

From a plot of stopping potential energy as a function of the frequency of incident light (qV vs f) it is possible to determine the value of h. Furthermore, the determination of the work function is also possible.

Equipment:

DMM	Mercury Vapor Lamp
Colored Filters	Variable Intensity Filters

Setup and Procedure:

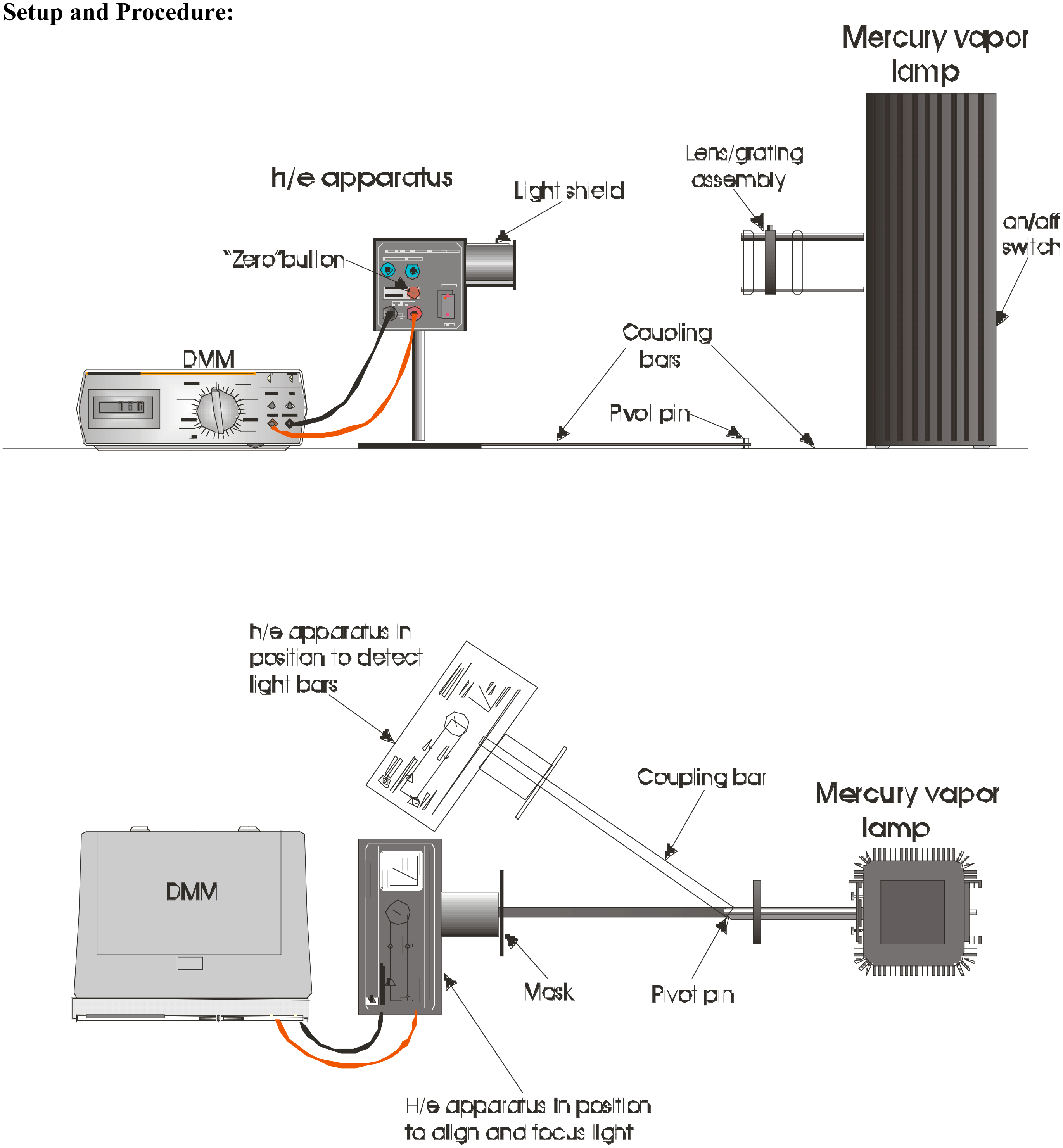
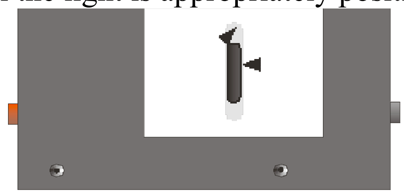


Fig. 1

1) Turn on the Mercury Vapor lamp and let it warm up for a few minutes. Use this time to remove the slides from the mask of the apparatus and place them on the base.
2) With the apparatus placed directly in front of the lamp, you will see a band of light on the white mask. If there is no band of light falling on the mask, pivot the apparatus on the coupling bar until the light is appropriately positioned.



3) With the light band covering the slot, roll back the light shield to reveal the photodiode inside the apparatus. If the light passing through the slot does not cover the photodiode, loosen the screw on the support rod and twist the apparatus until the light falls directly on the aperture of the photodiode, then retighten the screw.

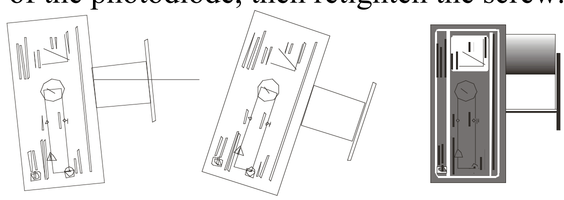


Fig.3

4) Loosen the screw on the lens/grating assembly and move it back and forth until the light falling on the photodiode is at its sharpest focus. Roll the light shield back into place.
5) Place the DMM near the apparatus and turn the selector dial to VDC setting. Connect the red port of the DMM to the red port of the apparatus. Do the same for the black ports.
6) Carefully rotate the apparatus about the pivot pin until you see five colored bands of light appear on the mask.

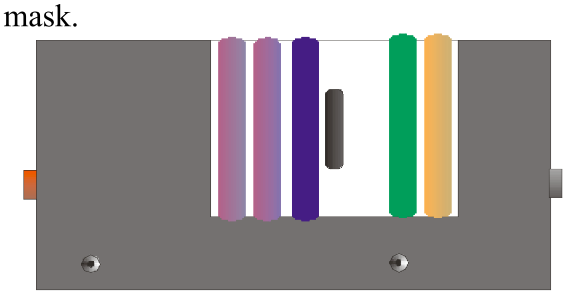


Fig.4

7) Align the green or yellow band of light over the slot in the mask and place the appropriate filter on the mask, using the magnetic strips to hold it in place.

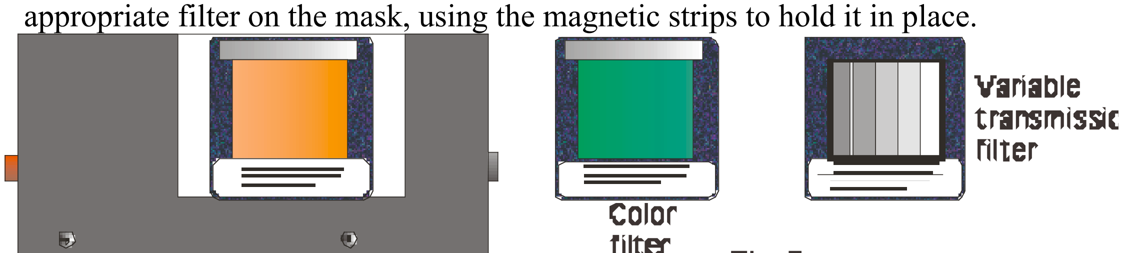


Fig.5

8) Now place the variable transmission filter over the color filter, aligning the lightest area (100% transmission) of the filter over the slot in the mask. Thus the light will pass through both the color filter and the variable transmission filter before entering the photodiode.

9) Turn on the apparatus and the DMM. Push the 'zero' button on the side of the apparatus and verify that the DMM reads a value of 0.00 Volts.

Part I: Varying the Intensity of the Incident Light

Procedure:

1) When the 'zero' button is released, the DMM will display a voltage. This is the measured stopping potential for this frequency and intensity of incident light. Record this value in the data table below.
2) Slide the variable transmission filter so the 80% grating is covering the slot in the mask. Push the zero button on the apparatus and record the reading.
3) Repeat this process until you have recorded the stopping potentials for each of the variable transmission filter values.
4) Remove the filters and reposition the apparatus such that a color other than yellow or green covers the slot in the mask. Replace the variable transmission filter and repeat the data collection process, being careful to zero the apparatus before each reading.

Data:

Color 1:	% Transmission	Stopping Potential (Volts)
	100	
	80	
	60	
	40	
	20	
Color 2:	% Transmission	Stopping Potential (Volts)
	100	
	80	
	60	
	40	
	20	

Analysis:

What effect does varying the intensity of the incident light have on the stopping potential? What does this imply about the kinetic energy of the ejected photoelectrons?

Part II: Varying the Frequency of the Incident Light

Procedure:

1) Remove all filters from the apparatus mask and place them on the apparatus base.
2) Adjust the position of the apparatus such that a colored band of light falls upon the mask.
3) Zero the apparatus, then record the stopping potential for that particular color in the data table.
4) Continue this process until data has been collected for each of the five colored bands of light

Data:

Color of Light	Frequency (10^{14} Hz)	Stopping Potential (Volts)
Yellow	5.19	
Green	5.49	
Blue	6.88	
Violet 1	7.41	
Violet 2	8.22	

Analysis:

What effect does varying the frequency of the incident light have on the stopping potential? What does this imply about the kinetic energy of the ejected photoelectrons?

Based your observations, does the data in this experiment support the wave model or the quantum model? Explain your conclusions.

Part III: The Relationship between Energy, Wavelength and Frequency
Data:

Use the data that you have already collected, complete this table of values:

Light Color	Frequency (10^{14} Hz)	Wavelength (10^{-9} m)	Stopping Potential (Volts)	Stopping Potential Energy (10^{-19} Joules)
Yellow	5.19	578		
Green	5.49	545		
Blue	5.88	435		
Violet 1	7.41	405		
Violet 2	8.22	365		

Analysis:

Either by hand, or using Excel or a similar program, prepare a graph of the stopping potential energy as a function of the frequency of the incident light. Extrapolate your best fit line to cross the vertical axis of the graph. You will need to begin the graph near the middle of the page, not at the bottom as you normally would. Find the slope of the graph, with units. Show your work below.

Calculate the percent error between the accepted value and the value calculated from your graph. Show your work below:

$$\%error = \left| \frac{Experiment - Theory}{Theory} \right| * 100 =$$

Identify the work function of the material from your graph. Include units:

Φ=________________

Conclusion: Briefly discuss the physics involved in the experiment, summarize the data, address potential sources of error and methods to reduce or eliminate them, and state whether or not the experimental results validate the theory.