 Name Hayden Fuller Section__________

38A – Photons

1) Write Einstein's relationship between the energy of a photon and the frequency of the electromagnetic wave that characterizes the photon beam. Explain in words what each term represents.

Relationship	Words
E=hf	Energy is directly proportional to frequency, with a proportion of planks constant

2) What is the approximate frequency, energy, and wavelength (in meters) of a green light photon in the middle of the visible spectrum?

Frequency (Hz) 6*10^14 Energy (Joules): 3.97*10^-19 Energy (eV): 2.3MeV Wavelength: 500nm

3) A beam of light has total power of 0.10 Watt. How many photons per second of wavelength 520 nm are needed to carry this power?

E=hf * N

2.616*10^17 photons/s

4) The flux per area of visible photons per second from the Sun arriving at the surface of the Earth is about $3x10^{21}$ $m^{-2}s^{-1}$. Assuming the average wavelength of visible photons from the Sun is 600 nm, estimate the intensity of sunlight in $Watts/m^2$.

hc/lambda

994.5 W/m^2

5) Light of wavelength 400 nm is incident on a surface with intensity of 0.5 W/m^2. The wavelength of the light is increased to 700 nm while maintaining the same intensity. Does the flux per area ($photons/m^2/s$) increase, decrease, or remain the same? Explain.

increase because energy per photon decreased and total energy stayed the same, so number of photons must increase

38B – The Photoelectric Effect – PhET Simulation

In the photoelectric effect experiment, a photon that is incident on a metal surface may be absorbed by the material, transferring all of its energy to an electron in the material. If, after absorption, the electron has sufficient energy, it may escape from the material, carrying the excess energy as kinetic energy. This simulation module will serve to introduce you to fundamental ideas prior to your doing the physical experiment.

Equipment: Computer capable of running the PhET Java simulation at https://phet.colorado.edu/en/simulation/legacy/photoelectric .

1) Run the Photoelectric App. Select "Sodium" as the metal "Target". Set the wavelength to 400 nm. Use the Intensity slider to increase intensity to 100%. Set the potential across the battery to 0.0 V.
   a) Do all of the ejected electrons travel at the same velocity?

      no

   b) What happens to the current *i* and the apparent speed v_{ele} of electrons as you move the potential slider positive?

      current remains the same, velocity of electrons increases

   c) What happens to the current *i* and the apparent speed of electrons v_{ele} as you move the potential slider negative?

      current drops to 0 and the electrons are accelerated backwards

   d) What is the potential V_s for which the fastest electrons turn around just as they reach the anode (right hand metal)? This is the stopping potential V_s for this situation. (λ = 400 nm, Sodium target, Intensity I = 100%).

      V_s = -.8

   e) What does decreasing the intensity I do to the stopping potential V_s? (Increase it; Decrease it; Leave it unchanged). Why do you think this is so?

      leaves it unchanged. Intensity increases the number of electrons, it has no effect on peak energy

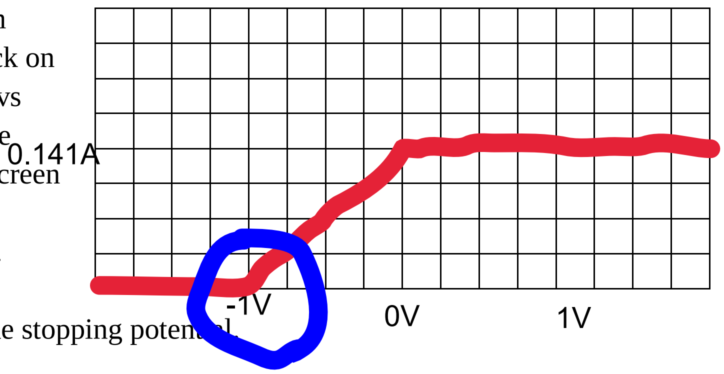
   f) What does decreasing the wavelength λ do to the stopping potential V_s? (Increase it; Decrease it; Leave it unchanged). Why do you think this is so?

      decrease it (increase magnitude), because it increases the max energy of electrons

   g) Set the potential to V = +8V and vary the wavelength λ until no electrons are emitted (the current $i \rightarrow 0$.) Write the wavelength λ to the right. This is the threshold wavelength for this material.

      λ_{th}= 540nm

2) Return the simulation to (400 nm, Sodium target, Intensity 100%, Voltage=0V). Click on the box to enable graphing of the current vs battery voltage. Sweep the battery voltage from -8 to +8 V. Rescale the plot on the screen so you can clearly see the behavior.



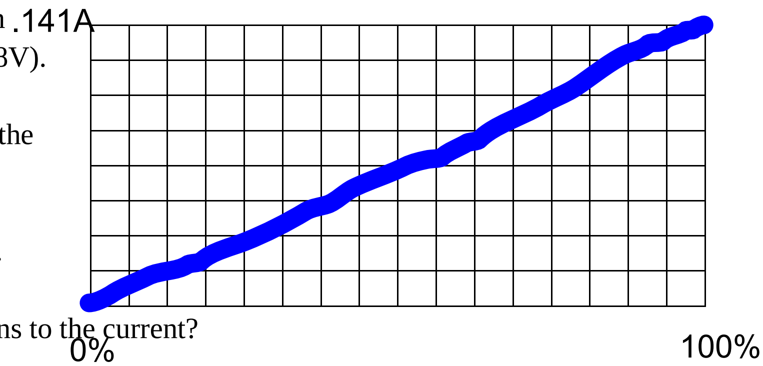
a) Sketch the plot in the box to the right.

b) Circle the point that corresponds to the stopping potential.

c) Why do you think the current stops increasing for positive voltage?

because 100% of the electrons are already flowing across

3) Set the simulation to (λ = 400 nm, Sodium target, Intensity I = 100%, Voltage V = +8V). Click on the box to display the Current vs Light Intensity. Vary intensity to display the graph.



a) Copy the graph in the box to the right.

b) If you halve the intensity, what happens to the current?

halves

This activity serves as an introduction to the upcoming photoelectric experiment. When you are doing the photoelectric experiment and questions arise go back and review this activity for clarification!

38C – Photoelectric Effect – Experiment

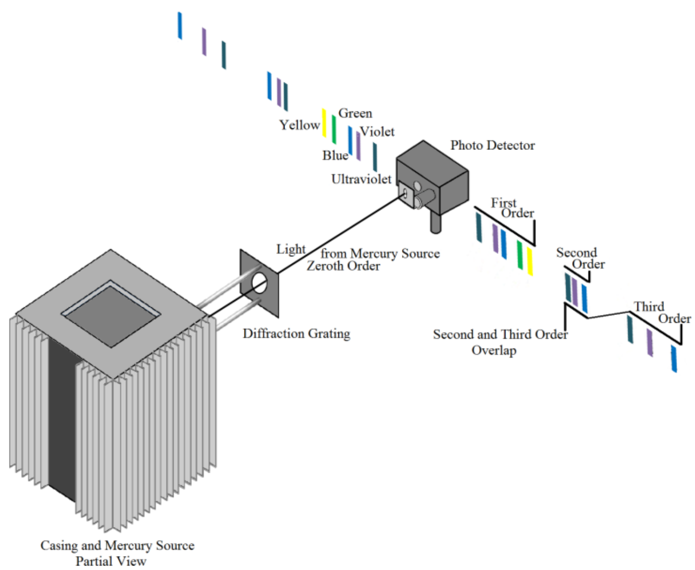
Equipment: High pressure – high intensity Mercury discharge lamp; Photoelectric sensor head; Digital Multimeter; 2 banana wires.

SAFETY NOTE: The mercury arc lamp emits intense visible and ultraviolet radiation that can damage your retina, vitreous humor, lens, and cornea. Do not stare directly at the arc lamp. Keep the shutter to the arc lamp closed when you are not taking measurements. Wear cool sunglasses if possible.

NOTE: KEEP THE MERCURY ARC LAMP LIT!. Otherwise it shortens the life of the (very expensive) lamp if turned off.

NOTE: DO SWITCH OFF the photoelectric detector when not in use to preserve the batteries.

The photoelectric head measures the stopping potential for emitted electrons by allowing the anode to charge until electrons are reflected back to the cathode. In order to work properly, it needs fairly intense light to be incident directly on the photocathode. It is therefore important to align the photoelectric head so that the light from the diffraction grating is incident on the photocathode. See sketch.



- Your light source should be turned on. If it is NOT, call a TA for assistance.

INSTRUCTIONS FOR BEAM ALIGNMENT

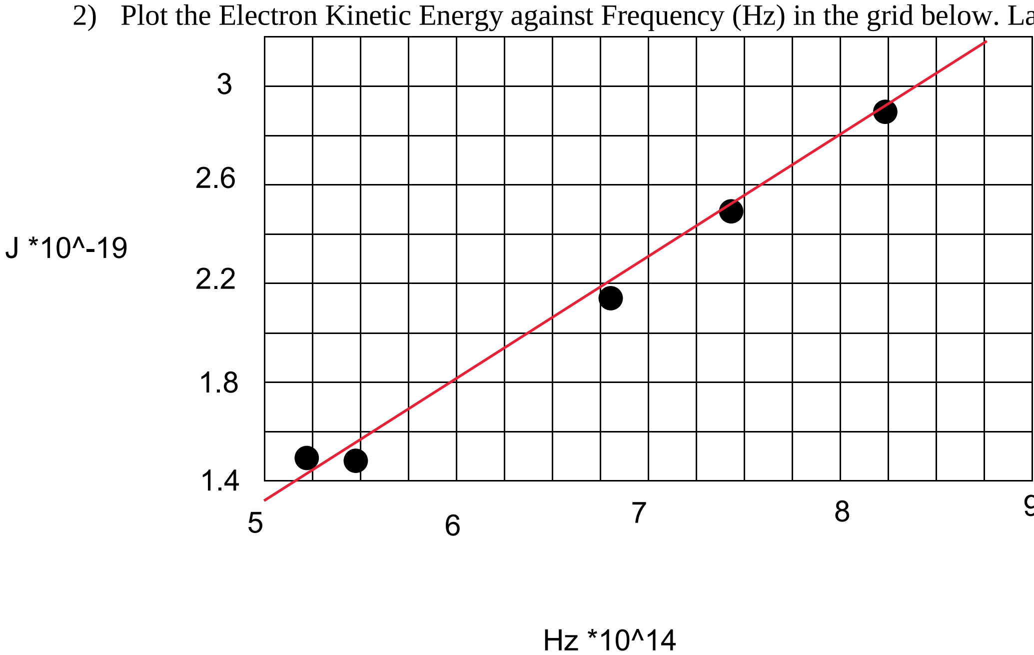
- Align the diffraction grating so it is directly above the pivot screw on the arm below. Lock the grating in place. The flat side of the grating/lens should be away from the light source.
- Align the photoelectric head so that the direct beam white light (Zeroth Order) from the lamp and grating enter the white mask and pass through the aperture to the OPENING OF THE COVER of the photodetector.
- *But Wait! Next step is critical. WITHIN* the photo detector box, there is a small opening on the cover of the photoelectric tube. It is critical that the light pass through that opening onto the photoelectric tube. If you cannot find it ask the TA or the Instructor!
- Once the light passes through this opening, lock the photodetector box in Place. Be sure it is mounted tightly. Do not move nor touch the photodetector box once it is locked in place.

- Reminder: The arm that the head is mounted on should pivot about a point below the grating so all wavelengths will properly pass into the cathode.
- Pivot the photodetector head until by moving ***ONLY the pivot arm*** the desired wavelength enters the photocathode (REMINDER – This is the opening of the cover *WITHIN* of the photodetector box).
- For green and yellow wavelengths use the filters to cut out stray UV light from hitting the cathode. (Neither of the ultraviolet line is directly visible, but the front of the photocathode head will fluoresce a pale lavender when UV is incident on it, making it possible to find the lines.) Check BOTH sides of the diffraction pattern and choose the one with the best brightness and sharpness.
- Turn on the photoelectric head and the multimeter. Set the multimeter to DC Volts.
- Depress and release the zero button on the detector head. Be careful that you don't shift the position of the detector when you do this. Wait a few seconds for the reading to stabilize. This should be the stopping potential. Record this stopping potential for each wavelength in the table below.

1) Fill in the table with the frequency ($f = c/\lambda$) of the electromagnetic radiation and the kinetic energy ($K = q_e V_{stop}$) of the electrons.

Color	Wavelength (nm)	Frequency ($\times 10^{14}$ Hz)	Stopping Potential V_{stop} (V)	Electron Kinetic Energy (J) *10^-19
Amber	578	5.19	.990	1.586
Kelly Green	546	5.49	.925	1.48
Indigo	436	6.88	1.350	2.16
Ultraviolet 1	404	7.43	1.540	2.47
Ultraviolet 2	365	8.22	1.800	2.88

2) Plot the Electron Kinetic Energy against Frequency (Hz) in the grid below. Label axes and scale.



3) Analysis of the graph. Using your calculator, find the slope, intercept, and the equation of the line. Your graphical equation will be in terms of *x* and *y*. Change these to the appropriate dependent and independent variables.

   a) Write down the equation of the line!

      y=5.0666*10^-34 x + 1.3*10^-19

   b) The slope of a straight line through your graphed points should yield Planck's constant! What value did you obtain? (Include units!)

      $h_{experimental}$= 5.066*10^-34 m^2 kg/s

   c) What is the literature value of Planck's constant in the same units as you deduced from your data? (Same units as above!) Is your experimental value close to the literature value? If not, why do you think it is different?

      pretty close

      $h_{literature}$= 6.626*10^-34 m^2 kg/s

   d) What is the physical meaning of the point at which your line intercepts the horizontal axis?

      cutoff frequency, when no electrons are emitted at low frequency

   e) What is the numerical value of the work function ϕ of your photocathode?

      ϕ = 1.3*10^-19 J