Homework 1

PHYS 485: Fall 2017
Due Date: 09/13/2017

To recieve fully credit please write legibly and clearly, show all required steps and calculations and answer any explicit questions in full sentences.

I. LIGHT [5]

1. Consider an electromagnetic wave described by $\vec{B} = B_0 \cos(kx - \omega t)\hat{y}$. Draw this wave at $t = 0$ and label axes, E, B, and its wavelength λ on your drawing. [2]
2. Draw the same electromagnetic wave but shifted by $\lambda/4$ on a plot directly below the one in part 1. [1]
3. If this light wave has frequency of $\nu = 4.2 \times 10^{14}$ Hz, then what is λ? What energy does a photon of this frequency have? [2]

II. PHOTOELECTRIC EFFECT [8]

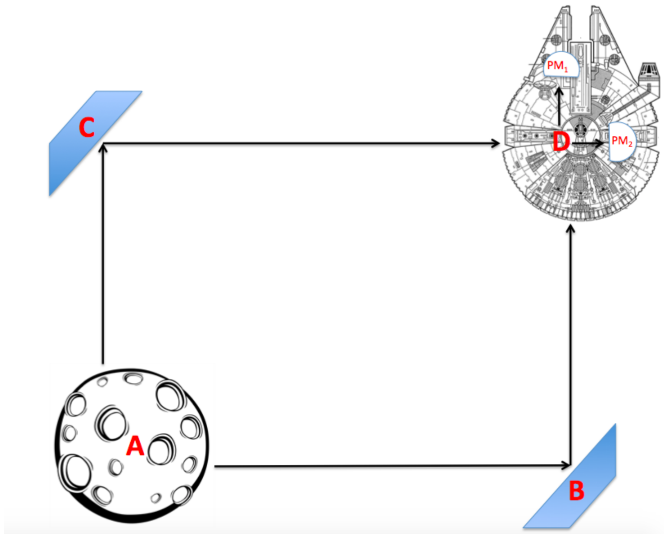
The amount of energy sufficient to remove an electron from the surface of gold i.e. the *work function* of gold is 5.10 eV. In a photoelectric device (see Fig. 1.12 in Townsend), upon bombarding the surface of a gold leaf with photons, electrons moving at the speed of 1.55×10^5m/s are detected.

1. What is the kinetic energy of one of *electrons*? Express your answer in eV. [1]
2. What is the energy of one of *photons*? [2]
3. What is the wavelength of one of these photons? [1]
4. What is the cutoff wavelength of light for gold? [2]
5. If the intensity of incident light is 3.0 W/m^2, what is the average number of photons n that strike the gold surface in 1 second if the linear dimension of the surface is 1 m? [2]

III. BEAM SPLITTERS AND THE "PHYSICS OF THE RESISTANCE" [9]

A long time ago in a galaxy far, far away, imagine that you join the Resistance and get tasked with using a Mach-Zender type beam splitter (see Fig. 1. 23 in Townsend and the sketch below) to transmit messages of wavelength λ from the planet D'Qar (point A) to the Millenium Falcon (point D). If PM_2, aboard the Millenium Falcon, records no signal the message is coded as 0 while a signal – a count – is coded as 1 thus allowing for communication. You are allowed to move the beam splitter at A. We assume that radiowaves are used and no atmospheric interference is present. Additionally, take B and C to be mirrors that reflect all of the radiowave, and A and D to be beam splitters that reflect 1/2 of the wave and transmit the other 1/2.

1. The effect of moving the beam splitter is to change the *path length difference* between the two possible paths to PM_2. Using your knowledge of conditions for complete constructive and destructive interference of waves taking two paths, give the minimum change in path length difference required to go from a full signal to no signal if the radiowaves have wavelength $\lambda = 1$ cm. Give your reasoning. [2]
2. What is the probability amplitude for the photon to reach PM_2 along the path ABD, denoted by z_{ABD}? What about z_{ACD}? Take careful note on whether the probability amplitudes for each leg of the path are multiplied or added and briefly discuss the correct approach. [4]
3. What is the probability for a photon to be detected by PM_2? Express it in terms of λ. Should you add or multiply the results of the previous question? Why? [3]



IV. MATTER WAVES [8]

A single electron is used in a double slit experiment where the distance between the slits and the detector is $L = 10$ m and the two slits are separated by $d = 0.1$ mm. In the detected intereference pattern the separation δy between the central maximum and the next adjacent maximum is 6.33 cm.

1. Draw a sketch of this set-up marking all the given quantities. [1]
2. What is the de Broglie wavelength $\lambda_{\rm dB}$ of this electron? Hint: use the small angle approximation $\sin\theta \simeq \tan\theta \simeq \theta$. [3]
3. What is the momentum of this electron? Would this momentum change if we used a photon with the same wavelength $\lambda_{\rm ph} = \lambda_{\rm dB}$? Explain. [2]
4. What is the kinetic energy of this electron? Would this energy change if we used a photon with the same wavelength $\lambda_{\rm ph} = \lambda_{\rm dB}$? Explain. [2]