PHYSICS HOMEWORK #103 PARTICLE PROPERTIES OF LIGHT
INTERFEROMETER

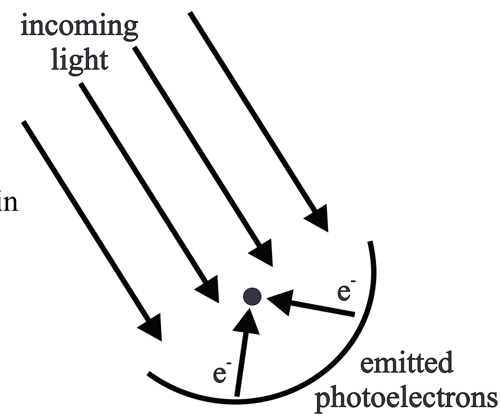
MICHELSON MORLEY INTERFEROMETER

1. Consider a stream which has a current of 4.5 m/s and which is 725 meters wide. A boat, which has a speed of 13.5 m/s in still water is to head directly across the stream, turn around and return to the near shore. A second boat is to head downstream a distance of 725 meters, turn around, and then return upstream the same distance.
   a. How long will it take for the first boat to reach the opposite shore and return?
   b. How long will it take the second boat to go downstream and back?
   c. If both began their trips at the same time, what will be the difference between their return times?

2. What results were Michelson and Morley expecting from their interferometer experiment?
3. What conclusions could logically be derived from the results of the Interferometer experiment?
4. Was the Interferometer experiment a success? Explain!

PHOTOELECTRIC EFFECT [KE = hf - ϕ]

5. What is the energy content [in Joules] of a light wave which has a wavelength of 4400Å?
6. What will be the energy content [in Joules] of a light wave which has a frequency of 5.25×10^{14} Hz?
7. A light wave has an energy content of 2.93×10^{-19} Joules, what will be the wavelength and frequency of this light wave?
8. A photoelectric experiment is performed and data are collected as shown in the table to the right.
   a. Determine the kinetic energies of the emitted photoelectrons.
   b. Determine the frequencies of the incoming light waves.
   c. Plot a graph comparing the energies of the emitted photoelectrons to the frequencies of the incoming photons.
   d. From your graph calculate an experimental value for Planck's constant.
   e. From your graph determine the cut off frequency for this surface and the resulting work function for this surface.
   f. Determine the equation describing the kinetic energies of the emitted photoelectrons as a function of the incoming light photons and the work function ϕ of the surface. [the "Photoelectric equation"]



WAVELENGTH	STOPPING POTENTIAL
4425Å	1.45 Volts
4975Å	1.13 Volts
6200Å	0.81 Volts
7075Å	0.56 Volts

9. Light, which has a wavelength of 890Å is incident on a photoelectric surface which has a work function [ionization potential] of -13.6 eV.
   a. What is the energy content [in Joules] of this incoming light wave?
   b. How much energy [in Joules] would be required to free the least strongly bound electron from this surface?
   c. What will be the kinetic energy of the emitted photoelectrons?
   d. What will be the velocity of the emitted photoelectrons?

10. What should have happened in the Photoelectric Effect according to classical wave theory? Include details!

11. How did Einstein explain the experimental results of the Photoelectric Effect? Include details!

Answers to opposite side: 12a. 2.32 x 10-18 J b. 1.08×10^{-18} J c. 1.54×10^{6} m/s 13. 3180Å
14a. 2.00×10^{-19} J [1.25 eV] b. 5.38×10^{-19} J [3.36 eV] c. 3.38×10^{-19} J [2.11 eV] 15. 1.87×10^{-19} J
16. 1.38×10^{-27} kg m/s 17. 16.2Å 18. 1.01Å 19. 2.24×10^{-35} m 20a. 1.44×10^{-27} kg m/s
20b. 2.88×10^{-27} kg m/s 21a. 1.21×10^{-27} kg m/s b. 231 N sec c. 1.48 m/sec^2 d. 235 days

PHYSICS HOMEWORK #104 PARTICLE PROPERTIES OF LIGHT WAVE PROPERTIES OF MATTER

PHOTOELECTRIC EFFECT [cont]

12. Light, which has a wavelength of 855Å, is shining on a photoelectric surface which has a work function of -7.724 eV for the least strongly bound electron [Copper].
 a. What is the energy of the incoming photon?
 b. What will be the kinetic energy of the emitted photoelectrons?
 c. What will be the velocity of the emitted photoelectrons?

13. The work function for Cesium is -3.90 eV. What is the wavelength of the least energetic light wave which can free a photoelectron from a Cesium surface?

14. Light, which has a wavelength of 3700Å, is used to illuminate a photoelectric surface. As a result of this illumination photoelectrons are emitted from the surface. A stopping potential of 1.25 Volts is required to reduce the photocurrent to zero.
 a. What is the maximum kinetic energy of the emitted photoelectrons?
 b. What is the energy content of the incoming photons?
 c. What is the work function of this surface in eV?

15. An atom absorbs a photon with a wavelength of 375 nanometers and then immediately emits a second photon having a wavelength of 580 nanometers. How much energy was absorbed by the atom in this process?

WAVE PARTICLE DUALITY [$h/\lambda = p$]

16. What is the momentum of a light photon which has a wavelength of 4800Å?

17. What will be the wavelength of an electron [$m_{electron} = 9.11 \times 10^{-31}$ kg] moving with a velocity of 4.5×10^{5} m/s?

18. What will be the wavelengths of the Hydrogen molecules [$m_{Hydrogen}$ atoms = 1.67×10^{-27} kg each] in a gas which is at a temperature of 35.0 °C? [Hint ! $KE_{ave} = 3/2\ kT$ where $k = 1.38 \times 10^{-23}$ J/°K and remember that Hydrogen is diatomic!]

19. What will be the wavelength of a baseball [$m_{baseball} = 0.78$ kg] moving toward home plate with a velocity of 38.0 m/s?

20. A light wave, that has a wavelength of 4600Å, strikes a mirror with an angle of incidence of 0.0° and reflects off.
 a. What is the momentum of this photon?
 b. What is the magnitude of the impulse delivered by the mirror to the light wave?

21. At the distance of the Earth from the Sun approximately 3.83×10^{21} photons, with an average wavelength of 550 nanometers, strike each square meter every second [called the solar flux]. Suppose that a huge "solar sail" made of metallized mylar [which behaves like a mirror] and which is 5.0 kilometers square is deployed by a spacecraft with a payload bound for the planet Mars. The mass of the payload and the solar sail is 156 kg. [1 nanometer = 10^{-9} m]
 a. What will be the momentum of a single photon of this light?
 b. What will be the magnitude of the impulse delivered to the solar sail each second?
 c. What will be the resulting rate of acceleration for this payload?
 d. How long will it take to increase the velocity of this space craft to 10% light speed?

Answers to opposite side: 1a. 107 s b. 121 s c. 14 s 5. 4.5×10^{-19} J 6. 3.48×10^{-19} J
7. 6780Å, 4.4×10^{14} Hz 8a. 2.32×10^{-19} J, 1.81×10^{-19} J, 1.30×10^{-19} J b. 6.77×10^{14} Hz., 6.03×10^{14} Hz.,
8b. 4.84×10^{14} Hz., 4.24×10^{14} Hz. d. 5.4×10^{-34} J s e. 2.5×10^{14} Hz. f. $KE = 5.4 \times 10^{-34} f + 1.7 \times 10^{-19}$ J
9a. 2.23×10^{-18} J b. 2.18×10^{-18} J c. 5.2×10^{-20} J d. 3.37×10^{5} m/s