PHYSICS 2P51: Assignment 1

1. **The photoelectric effect**
   The photoelectric effect provided some of the first evidence for the existence of photons. Readings: (1P22 or 1P92 notes: pp. 343-345 in Meyer Arendt)

   (a) Is an electron accelerated in the same or opposite direction when placed in an external electric field? Explain using an equation.

   (b) What would the motion of an electron be under the influence of incident light assuming the electromagnetic wave model?

   (c) If the photoelectric effect could be explained by the electromagnetic wave model (in reality it cannot), explain how the electrons might be ejected. item What is the name for an electron that has been ejected from a metal surface after light has been absorbed?

   (d) Does the cut-off wavelength correspond to the highest or lowest wavelength of light that will eject electrons? Explain.

   (e) Light of 350 nm hits a surface with work function 2.75 eV.

      i. What is the highest kinetic energy of electrons ejected by the surface in joules?

      ii. What is the stopping potential (in Volts)?

      iii. What is the cut-off wavelength of the light?

2. **Wave and Particle Descriptions of Laser Light**
   A 5 mW HeNe laser emits photons of a single wavelength 632.8 nm in a beam of light in a vacuum. The beam diameter diverges slightly and at a distance 3 m from the laser output, the diameter of the beam is 2 mm.

   (a) Determine the energy (in eV) of one HeNe laser photon.

   (b) Determine the intensity (in W/m^2) of the laser beam at the point that is 3 m from the laser output, along the direction of the beam.

   (c) Determine the photon flux (number of photons per unit area) at the point that is 3m from the laser output, along the direction of the beam.

(d) If instead one uses the electromagnetic wave model of light, determine the amplitude of electric field in N/C and the magnetic field in T at the point 3m from the laser output, along the direction of the beam.

3. **Greenhouse effect**

   (a) One can assume that both the sun (T=5800 K) and the earth (T = 20°C) are perfect black body radiators. Using excel, or some other program, calculate $M(\lambda)$, the power emitted per unit area per unit wavelength for the earth as a function of wavelength between 0.1 and 100 μm. Make a similar calculation for the sun between 0.1 and 100μm. Plot both curves on a log-log plot. Remember axes titles, units and graph title.

   (b) Using Wien's displacement law, determine the wavelength of maximum intensity for the sun and for the earth (in μm).

   (c) In what portions of the electromagnetic spectrum (ultraviolet, visible, infrared, radio wave etc.) does the greatest amount of radiated energy occur for the sun and for the earth?

   (d) In the plot of the absorption of various gases versus wavelength of the light, what is the physical process behind the absorption bands in H_2O in the vicinity of $1\mu\text{m} < \lambda, 10\mu\text{m}$. What is the physical process for absorption by O_2 for $\lambda < 0.3\mu$m

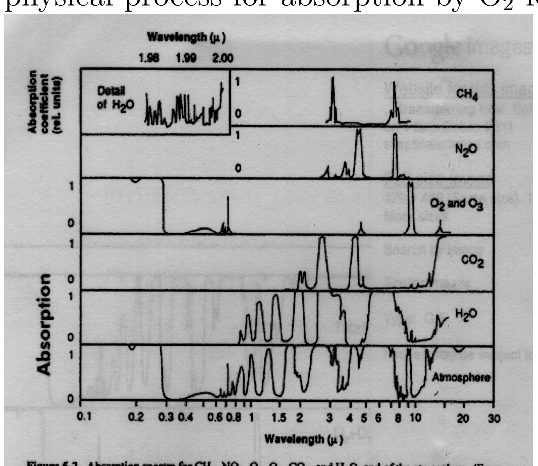

Figure 5-2. Absorption spectra for CH_4, NO_2, O_2, O_3, CO_2, and H_2O, and of the atmosphere. (From R. G. Fleagle and J. A. Businger [2006] after J. H. Howard [519] and R. M. Goody and G. D. Robinson [514])

(e) By comparing your graphs of the blackbody spectra of both the sun and the earth with the absorption spectra of N_2, O_2, CO_2, H_2O gases, shown in the graph below explain what is meant by the term "greenhouse effect". Consider the chemical composition of the atmosphere in your answer.