Phys106, II-Semester 2019/20, Tutorial 3, Fri 24.1.

Work in teams of three. Do "Stages" in the order below. When all teams finished a stage, make sure all students at your table understand the solution and agree on one by using the board (in Studio-Air), or paper sheets (in L1).

For this tutorial, you may find the following list of physical constants convenient:

- $h = 6.62607004 \times 10^{-34}$ J s
- $\hbar = 1.054571800 \times 10^{-34}$ J s
- $e = 1.60217662 \times 10^{-19}$ C
- $k_B = 1.38064852 \times 10^{-23}$ J/K
- $c = 2.99792458 \times 10^{8}$ m/s

For unit prefixes, use internet.

Stage 1 (i) For the following photon frequencies, determine the name of their part of spectrum (radio, visible....), their energy in Joule and their energy in electron Volts (eV).

- $\nu = 30$ THz
- $\nu = 2 \times 10^{15}$ Hz
- $\nu = 10^{21}$ Hz
- $\nu = 10$ kHz
- $\nu = 4 \times 10^{18}$ Hz

(ii) Compare the energies you found in (i) with the following table of energy *scales* associated with physical processes/objects. For which combinations does the *order of magnitude* match (best)?

- Energy scale of excitation of an atomic nucleus $E_{nuc} \approx 1$ MeV.
- Ionising an inner shell electron from a heavy atom $E_{ion} \approx 30$ keV.
- Exciting an electron in a dye-biomolecule to its lowest excited state $E_{dye} \approx 2$ eV.
- Energy of vibrations of molecular bonds, $E_{vib} \approx 2 \times 10^{-20}$ J.
- Resonance energy of a large linear antenna, $E \approx 1 \times 10^{-30}$ J.

(iii) For the matching pairs, find the wave length of the photon and the sizescale associated with the matching physical process/object in list (ii). What common fact do you see. It turns out, which object elm waves interact with most strongly is mostly determined by the match in energy, not so much match between size/wavelength. Discuss. Why could that be like this?

Stage 2 **Wien's displacement law** says that the peak of the black body spectrum is at at $h\nu_{max} = 2.8214 k_B T$ (you can derive this later using mathematica). Now only find the temperature ranges for which the peak of the BB spectrum is within a certain part of the elm spectrum (radio, visible....), for all those parts.

Stage 3 Discuss on your table how Planck's calculation trick [that energy must have discrete quanta Eq. (23)], can be understood once we know about photons.

Stage 4 (i) Answer the following questions on the photo-effect:

- The work function for sodium is 2.3 eV. What is the maximum kinetic energy of electrons you can get when shining blue light on it?
- Using UV light ($\lambda = 150$ nm) on silver, you have to apply a counter voltage of at least 4 V to stop any electrons from arriving. Infer the work function of silver.
- Calcium has a workfunction of 3.2 eV, if you shine light with intensity $1W/cm^2$ and frequency $\nu = 6 \times 10^{14}$ Hz do you see photo electrons? What happens if you increase the intensity?
- What if instead you shine light with intensity $1W/cm^2$ and frequency $\nu = 1 \times 10^{15}$ Hz, do you see photo electrons? What happens now if you increase the intensity?

(ii) Use the online simulator at: http://vlab.amrita.edu/. For simulator use the login and password provided by TAs. Perform the virtual measurements described there and interpret them in the context of the lecture.