

# Phys106, II-Semester 2018/19, Assignment 3

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*Hint: For all these questions (and later ones) you may use the math software `mathematica`, available from CC. The little overhead in familiarising yourself with it now, will pay off manyfold later, regardless of your major.*

1. Write the Rayleigh Jeans law in terms of wavelength, i.e. we want  $u(\lambda)d\lambda$ , the total energy within a wavelength interval  $d\lambda$ . Take care in converting the differential  $d\nu$ .
2. Ultraviolet light of wavelength 300 nm and intensity 5.00 W/m<sup>2</sup> is directed at a Lithium surface. (a) Find the maximum kinetic energy of the photoelectrons (For the workfunction ( $\phi$ ) of Lithium see the book "Concept of Modern Physics by Arthur Beiser" ) (b) if 0.5 percent of the incident photons produce a photoelectron, how many electrons are emitted per second if the surface has an area of 4 cm<sup>2</sup>. Recall 1 Watt = 1J/s, i.e. energy per unit time.
3. Consider the light emitted by a 25 W room lamp. Assume this is all yellow light with  $\lambda = 570$  nm (in reality it is a mix of colors). How many photons per second are there? Why would quantum physics frequently be not that important in determining what happens due to this light?

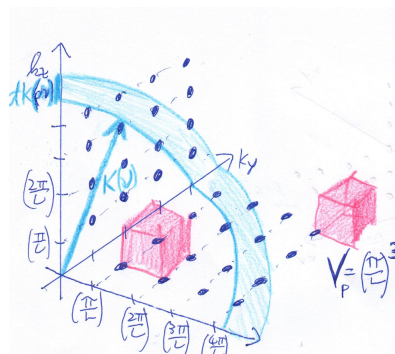


Figure 1: (for question 4) Sketch of reciprocal space. Big dots indicate allowed 3D wave-vectors. Red shade indicates the volume effectively taken by one of these dots.

4. Derive Eq. (20) of the lecture, that the number of standing waves within a cavity that have a frequency between  $\nu$  and  $\nu + d\nu$  is

$$G(\nu)d\nu = \frac{8\pi\nu^2}{c^3}d\nu \quad (1)$$

Proceed as follows:

- (i) Confirm that condition (16) for a standing wave can be re-written in terms of wave number as  $k = \frac{\pi}{L}n$  for  $n = 1, 2, 3, \dots$ .

- (ii) 3D waves have a wave vector  $\mathbf{k} = [k_x, k_y, k_z]^T$ . The relation to frequency is  $2\pi\nu/|\mathbf{k}| = c$ .
- (iii) Now for 3D standing waves that fit into a cubic 3D cavity of volume  $V = L^3$ , the condition is  $k_j = \frac{\pi}{L}n_j$  for  $n_j = 1, 2, 3, \dots$  and  $j \in \{x, y, z\}$ .
- (iv) That means, that in the space of all vectors  $\mathbf{k}$ , and allowed standing wave must always lie on one of the dots in Fig. 1. This space is called reciprocal space.
- (v) To infer  $G(\nu)d\nu$ , we have to now “count” the number of dots within a spherical shell of radius  $k(\nu)$  and thickness  $dk(d\nu)$ . We use that each dot effectively occupies a volume  $(\frac{\pi}{L})^3$ . Also take into account that each wave can have two different polarisations (directions of the E-field vector within the wave), so we have to count it twice.
- (vi) Divide by the total volume of the cavity to get the number of waves *per unit volume*.
- (vii) Use all these steps to show Eq. 1 above.