Hint 2

IMPORTANT! The next task is both a hint and an alternative to the main task. Three important points:

1. You can continue to send the solution to the main problem.
2. At any time before the final deadline, you can switch to *alternative task*. If you do this, write at the very beginning of the solutionI'm moving on to an alternative task!. In this case, you get an additional coefficient of 0.7, which is multiplied by the old coefficient, and the solutions to the main problem are not checked from this point on. Be careful!
3. The task consists of several items. The penalty multiplier earned by **before** is applied to all points. In the future, each item is evaluated as a separate task. If you send a solution without any item, this item's solution is considered as Incorrect. For more information about scoring points for composite tasks, see the rules of the Cup.

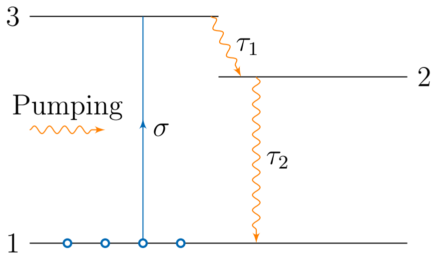
Alternative Problem

We consider a medium for which our theory from the main problem of energy levels and transitions between them is true. If in a certain process it turned out that the number of electrons is higher at a higher level than at a lower energy level, and radiative transitions are possible between these levels, then they say that the system implements *level population inversion*. If such a regime is implemented, then if a photon with a frequency equal to the resonant frequency enters the system, the probability that the stimulated emission will occur is higher than the probability that the photon will be absorbed. In other words, the probability of amplification of electromagnetic radiation is greater than the probability of its attenuation. Such a situation is realized in the active medium of a laser during the generation of laser radiation. There are two standard level systems in which such a situation is possible: three-level system and four-level one. Let's consider them in more detail.

Three-level system

In the figure a three-level system is shown. Level 1 will be called the ground, levels 2 and 3 will be called excited. By pumping we mean a process that transfers electrons from the first level to the third (this can be radiation from a lamp, inelastic impacts, etc.). We assume that the pump is characterized by the absorption cross section σ.

From the third level to the second, a very fast nonradiative transition occurs with a characteristic time of τ_1. We assume that from the second level to the first there are nonradiative transitions and transitions due to spontaneous emission. We will characterize both of these transitions with the lifetime of the second level tau_2.

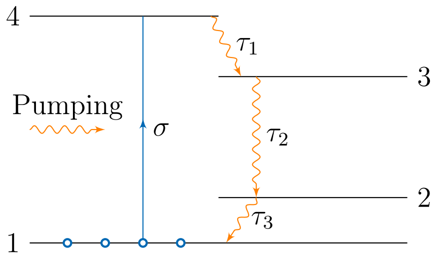


1. In the stationary approximation, find the dependence of the populations of the second and first levels $n_1(F)$ and $n_2(F)$ on F, where F is the value analogous to the photon flux density from the main problem. Plot them on one chart. (2 points)
2. At what value of F does population inversion occur? (0,5 points)
3. In what conditions a third-level population becomes zero at high values of F? (0,5 points)

The total electron concentration is known and is equal to N, the absorption cross section σ and the characteristic times τ_1 and τ_2 are also considered known.

Four-level system

The four-level system is similar to the previous one, but laser generation occurs during transitions from the third to the second level (see figure). In this case, relaxation from the second level to the first occurs in a negligible time, i.e. we can assume that the electrons, getting to the second level, do not live there and instantly fall on the ground (first) level.

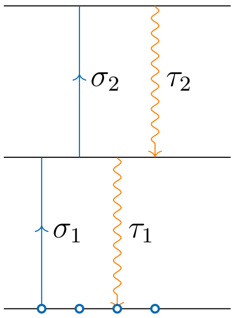


1. In the stationary approximation, find the dependence of the third level population on the pumping $n_3(F)$ and plot it. (1,5 points)
2. At what value of F does population inversion occur? (0,5 points)

The total electron concentration is known and is equal to N, the absorption cross section σ and the characteristic times τ_1 and τ_2 are also considered known.

Reverse-saturable absorption

Consider the three-level system shown in the figure. Radiation with a photon flux density of F acts on the medium, as a result of which the electrons begin to redistribute along energy levels. Consider that 4 types of transitions are possible: the transition of the electron of the lower level to the middle one with the photon absorption cross section σ_1, the transition of the electron from the middle level to the upper one with the photon absorption cross section σ_1, as well as two non-radiative transitions with characteristic relaxation times τ_1 and τ_2. With an increase in the value of F, it can happen that an electron, getting to the second level, does not have time to return to the first one, and makes a transition to a higher level, after which it never returns to the first. This is the phenomenon of reverse-saturable absorption.



1. In the stationary approximation, find the dependence of the populations of the first and second levels $n_1(F)$ and $n_2(F)$ on photon flux density F. Plot them on one chart. (2 points)

2. Find the dependence of the absorption coefficient α on the magnitude of photon flux density F (in the stationary approximation). Plot it. (2 points)

3. At what value of F does the phenomenon occur? (0,5 points)

4. Under what conditions does the population of the first level become zero? (0,5 points)

The total electron concentration is known and is equal to N, the absorption cross section σ_1 and σ_2 and the characteristic times τ_1 and τ_2 are also considered known.