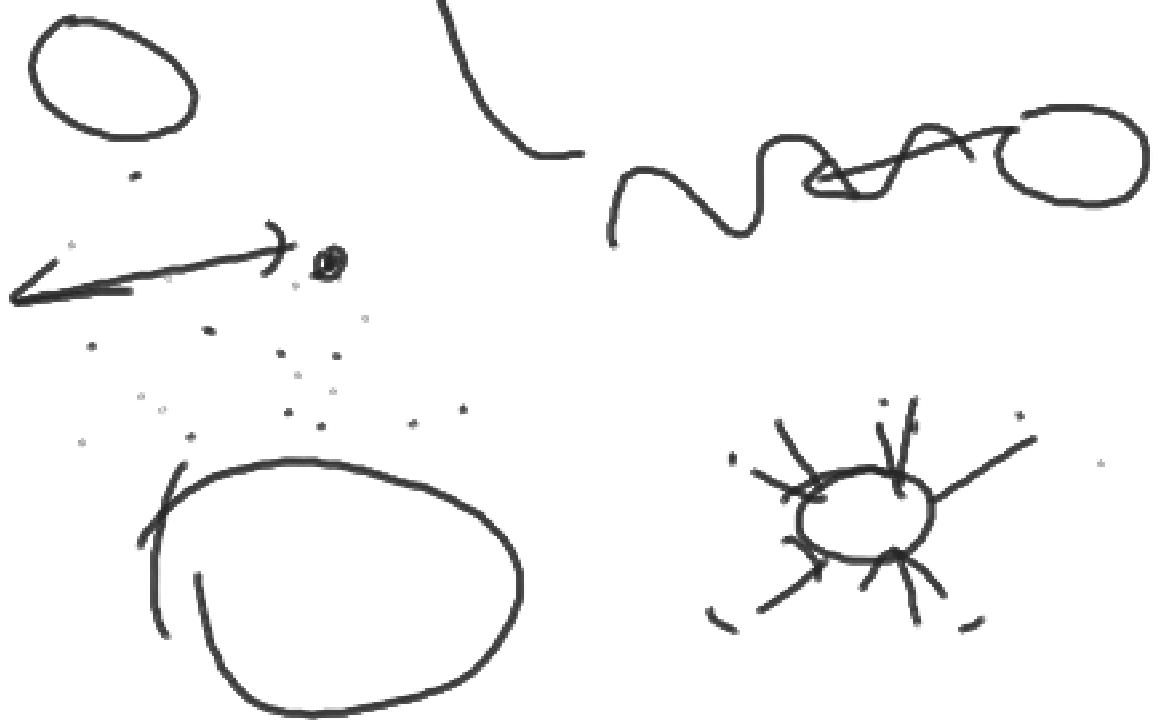
LASER

Light Amplification through Stimmulated Emission of Radi
ation

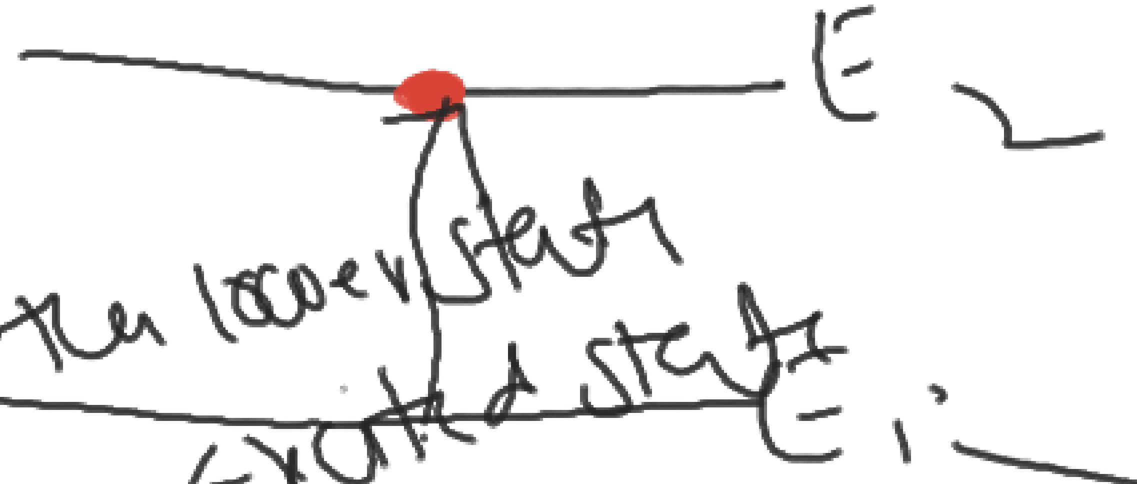


1916

1960 → T H Maiman

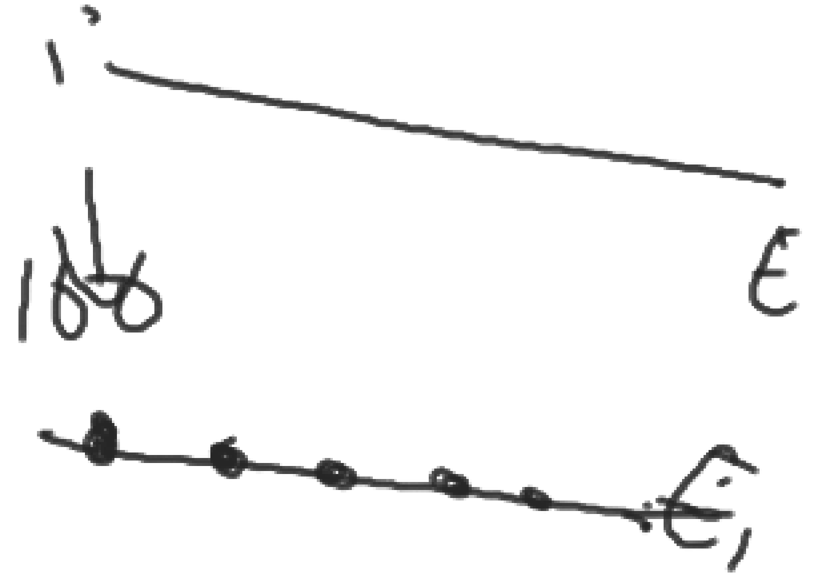
1961 → A Javan
↓
gay

Before



After

10^{24} at



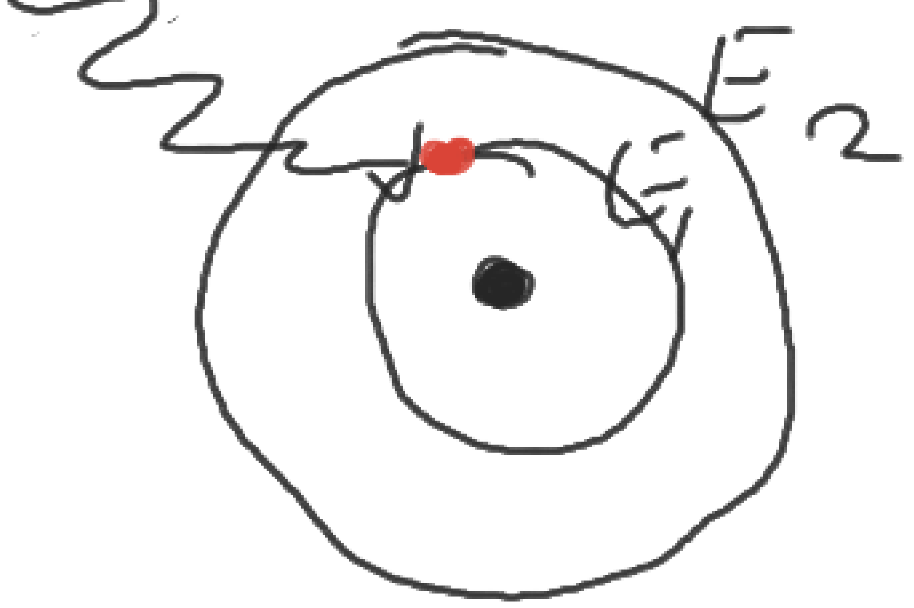
$A \rightarrow$ is an atom in the lower state

$A^* \rightarrow$ " " excited state

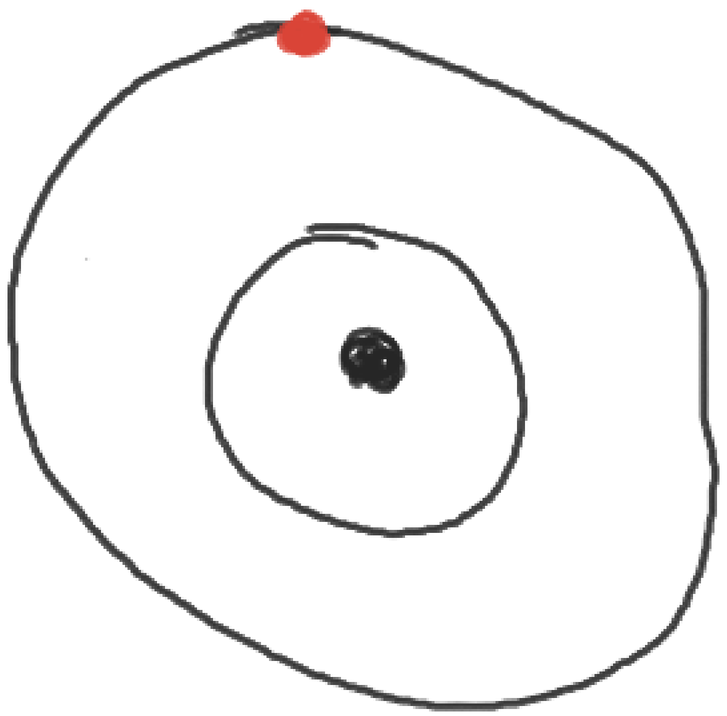
Absorption :-

$h\nu = E_2 - E_1$

$A + h\nu \rightarrow A^*$



Before



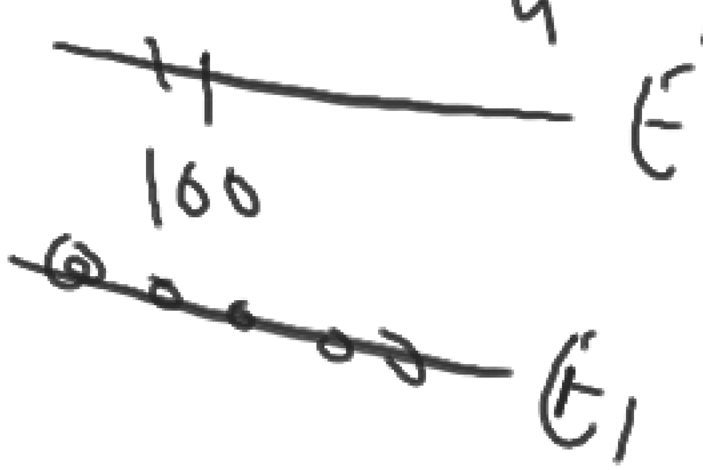
After

The Probability that an absorption transition occurs is proportional to the photon density $\rho(\nu)$

$$P_{12} \propto \rho(\nu)$$

N_1 = no. of atoms at ground state

N_2 = no. of excited state



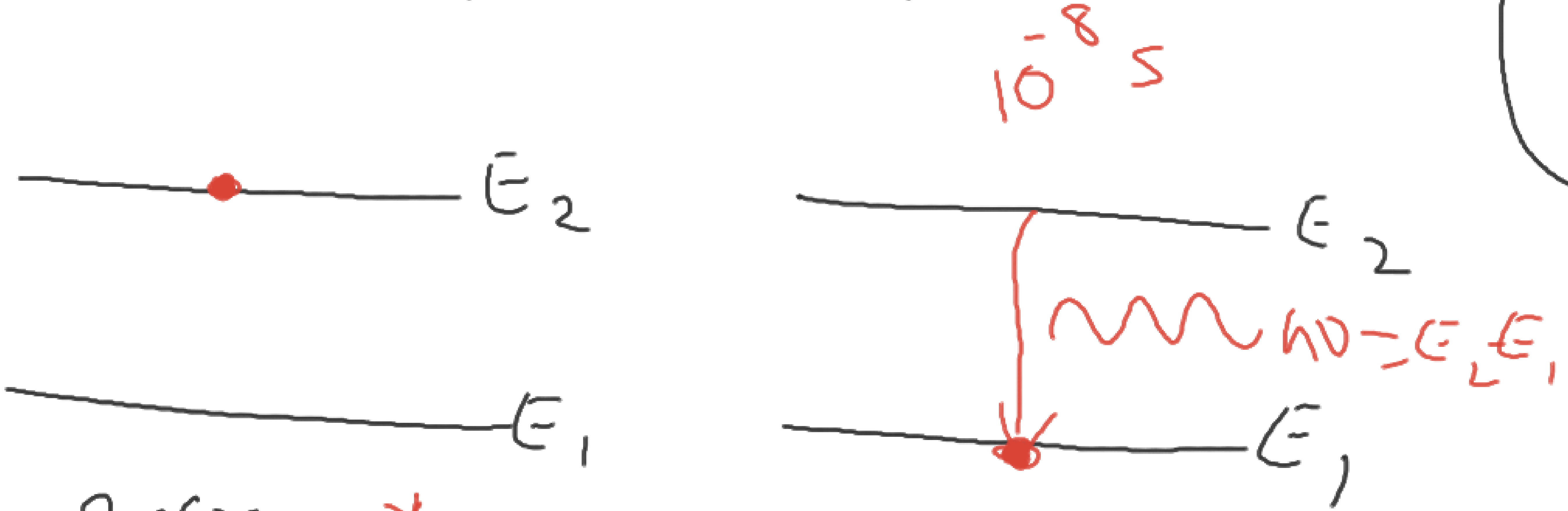
$$P_{12} = B_{12}\,\rho(\nu)$$

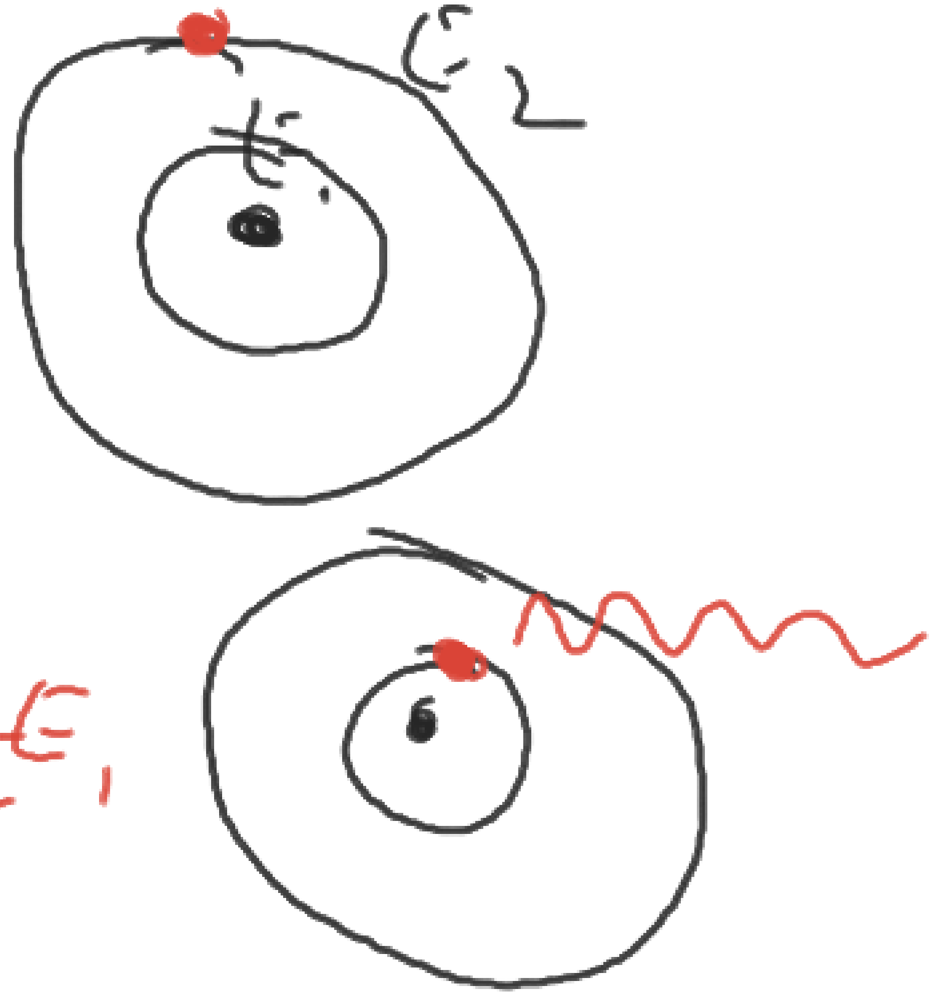
B_{12} is constant of proportionality. B_{12} is known as the Einstein coefficient for absorption

The total no. of atoms N_{ab} excited during at time

$$N_{ab} = B_{12} N_1 \rho(\nu) \quad \text{— (1)}$$

2. Spontaneous Emission



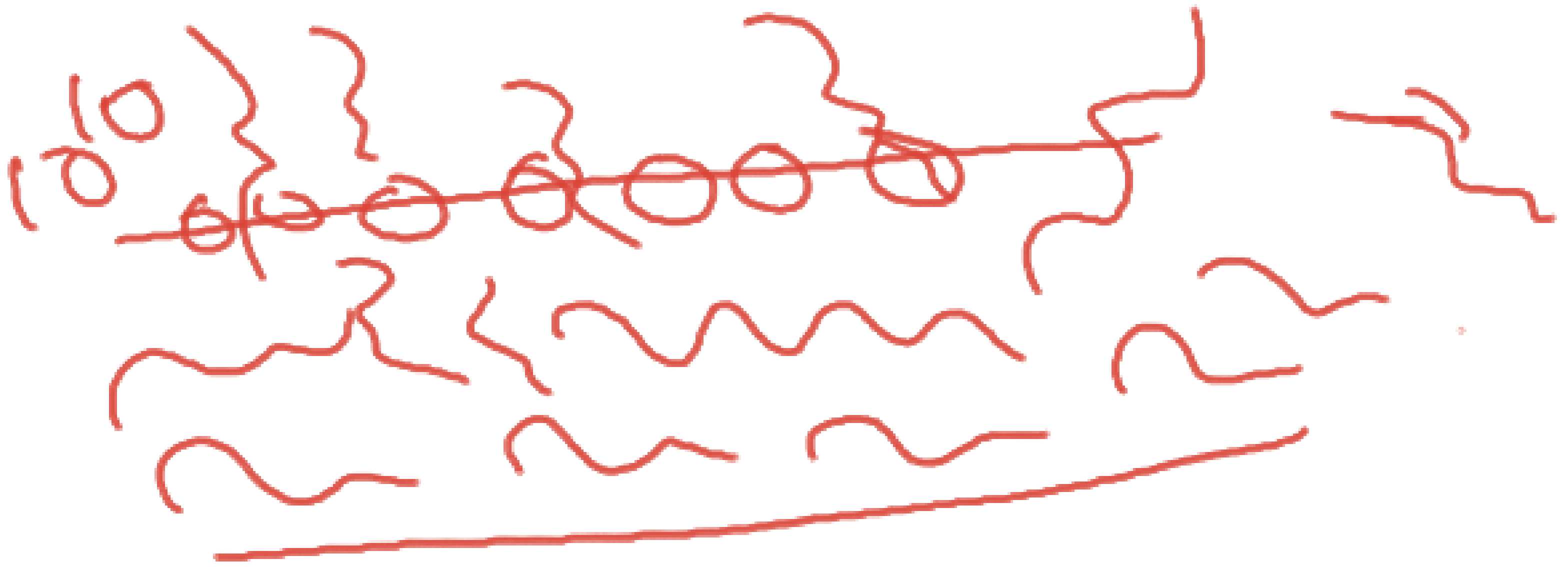


Before $\quad A^* \rightarrow A + h\nu \quad$ After

$P_{21} = A_{21} \rightarrow$ Einstein coefficient for spontaneous emission

$\frac{1}{A_{21}}$ is a measure of the lifetime of the upper state against spontaneous transition to the lower state

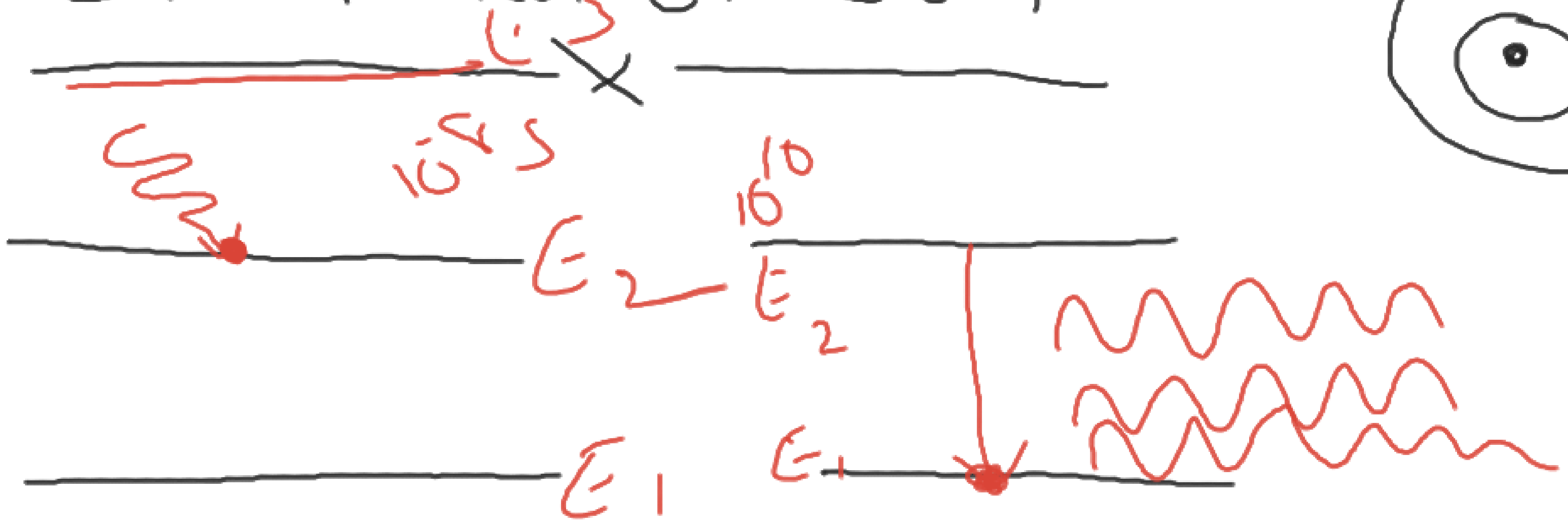
$$N_{sp} = A_{21} N_2 \Delta t \quad (2)$$



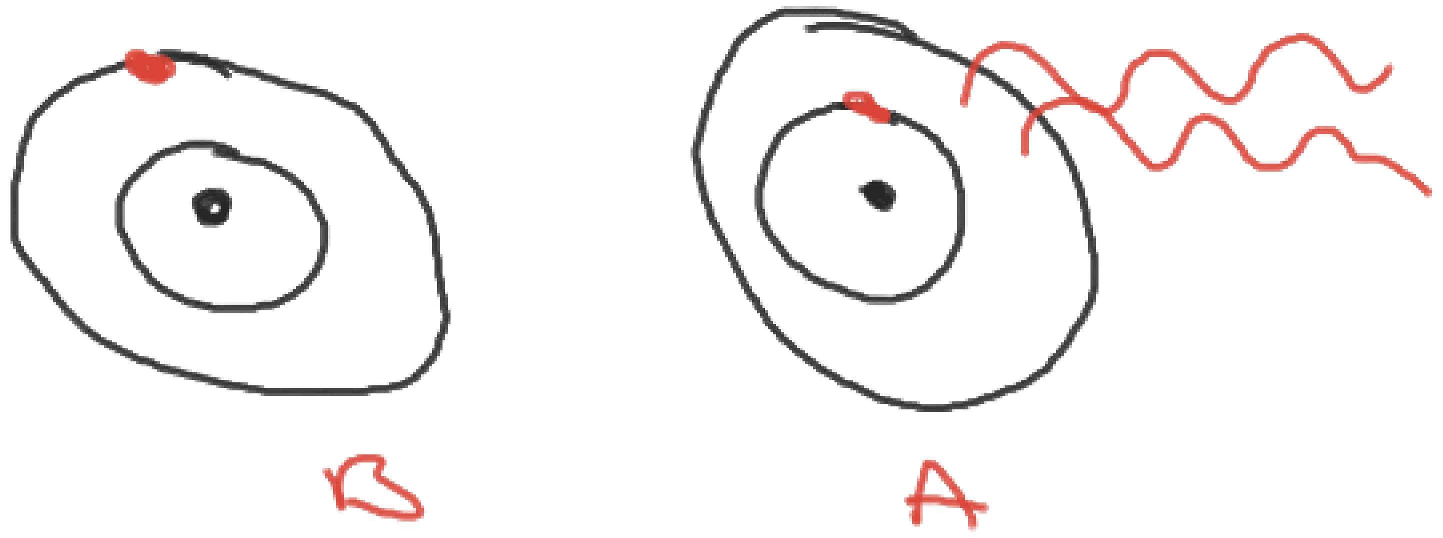
10^{24}

1. The instant of transition
2. Direction of the emission of the photon
3. Phase of the photon
4. Polarization state of the photon

3. Stimulated Emission



Before   After



$$P_{21} \propto \rho(\nu) \Rightarrow P_{21} = B_{21}\rho(\nu)$$

$$A^* + h\nu \longrightarrow A + 2h\nu$$

$B_{21} \to$ Einstein coefficient for stimulated emission

$$N_{st} = B_{21} N_2 \rho(\nu)\,\Delta t \quad \text{— (3)}$$

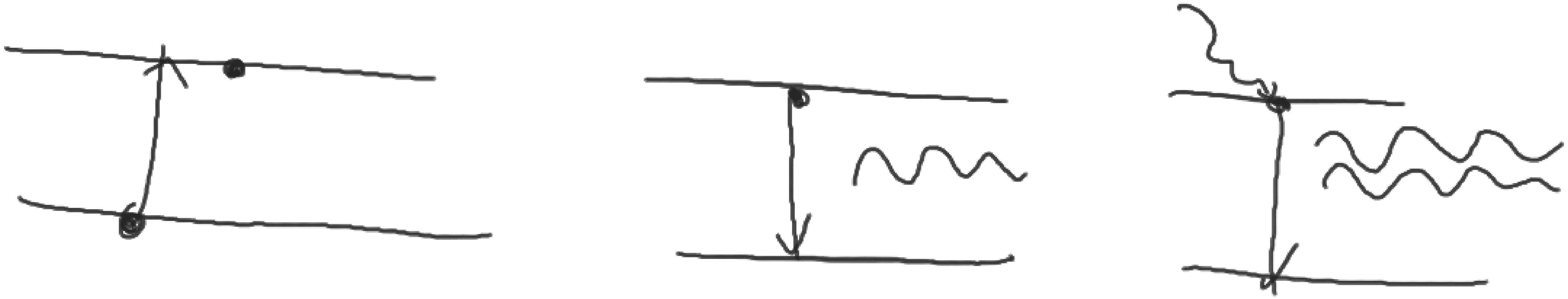
multiplication of stimulated photon

2^0 2^1 $I = nI$ 2^2 2^3 . . . . 2^n

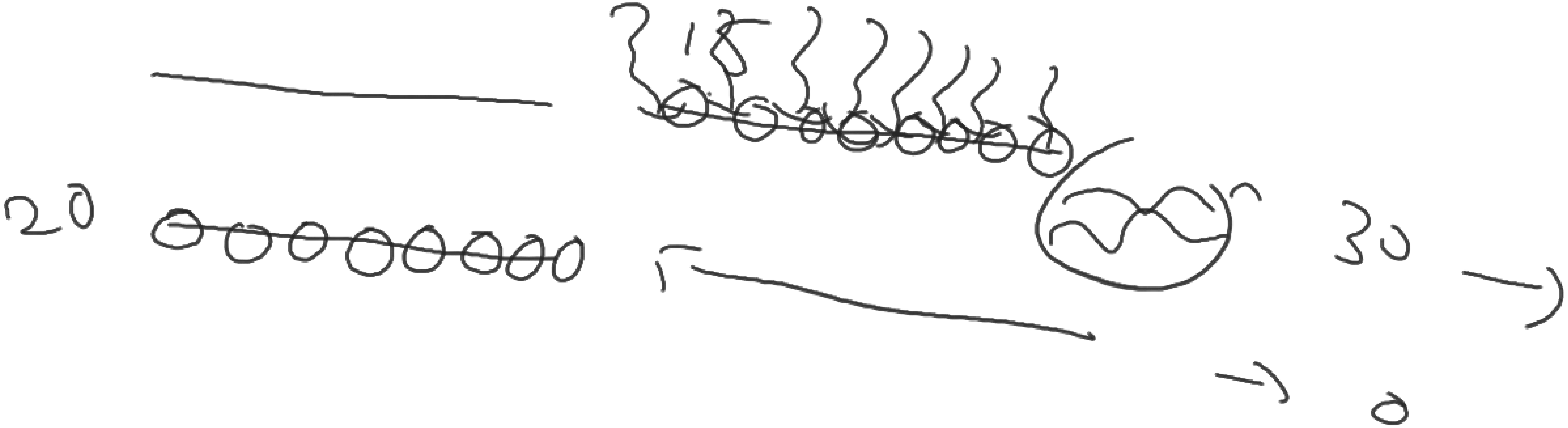
$I = n^2 I$

phon

Steady state condition



10^{24}



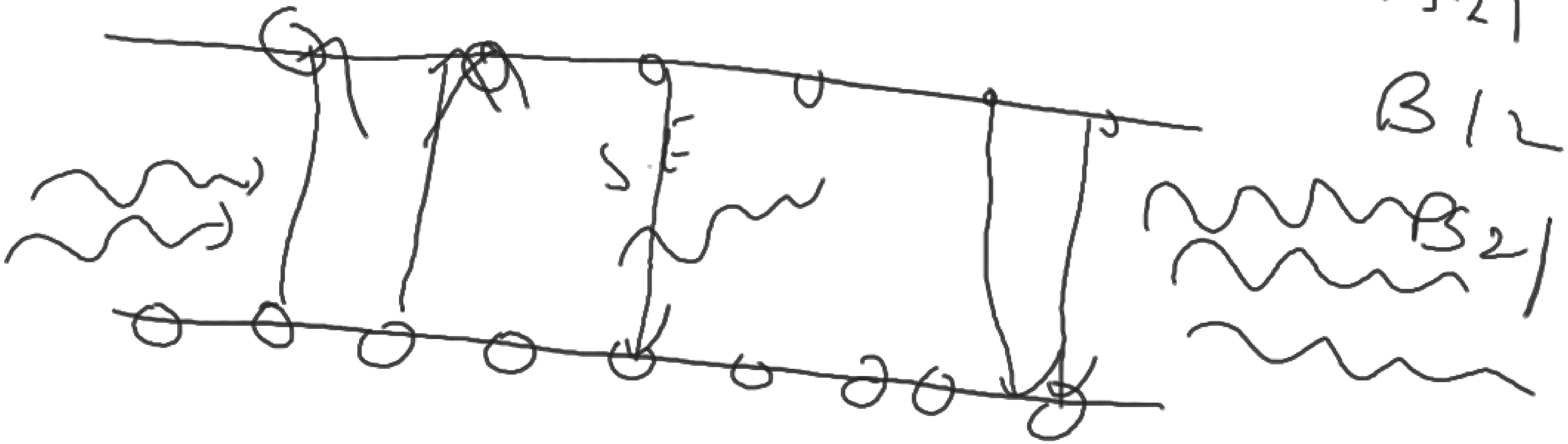
$$N_{ab} = N_{sp} + N_{st}$$

$$B_{12} N_1 \rho(\nu) \Delta t = A_{21} N_2 \Delta t + B_{21} N_2 \rho(\nu) \Delta t$$

$$B_{12} N_1 \rho(\nu) = A_{21} N_2 + B_{21} N_2 \rho(\nu)$$

A_{21}

B_{12}



1. The atomy and the radiation are in Thermal Equi

2. The radiation is identical with B.B radiation & Consistent with Plank's radiation law for any value of T

3. The population density N_1 & N_2 at the lower and upper + E.L repectively constant in time and are distributed according to the Boltzmann law in energy levey

N_2 ———— E_2

N_1 ———— E_1

$$\frac{N_2}{N_1} = e^{-(E_2-E_1)/KT} = e^{-h\nu/KT}$$

$$\boxed{\frac{N_1}{N_2} = e^{h\nu/KT}}$$

$$N_{ab} = N_{sp} + N_{st}$$

$$B_{12}\rho(\nu)N_1 = A_{21}N_2 + B_{21}N_2\rho(\nu)$$

$$\rho(\nu)\left[B_{12}N_1 - B_{21}N_2\right] = A_{21}N_2$$

$$\rho(\nu) = \frac{A_{21}N_2}{\left[B_{12}N_1 - B_{21}N_2\right]}$$

Dividing $B_{12}N_2$

$$\rho(\nu) = \frac{A_{21}/B_{12}}{\left[\frac{N_1}{N_2} - \frac{B_{21}}{B_{12}}\right]}$$

$$\frac{N_1}{N_2} = e^{h\nu/KT}$$

$$\rho(\nu) = \frac{A_{21}/B_{12}}{\left[e^{h\nu/KT} - \frac{B_{21}}{B_{12}}\right]}$$

$$\rho(\nu) = \frac{A_{21}}{B_{12}}\left[\frac{1}{e^{h\nu/KT} - \frac{B_{21}}{B_{12}}}\right]$$

$$\frac{A_{21}}{B_{12}} =$$

$$\rho(\nu) = \frac{8\pi h\nu^3}{c^3} \frac{1}{e^{h\nu/KT} - 1}$$

$$\rho(\nu) = \frac{8\pi h\nu^3}{c^3}\left[\frac{1}{e^{h\nu/KT} - 1}\right]$$