



## ENGINEERING PHYSICS

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- **Class #35**
- Rates of absorption and emission and thermal equilibrium
- Planck's expression for Energy density
- Einstein A and B Coefficients

# ENGINEERING PHYSICS

## Unit IV : Review of concepts leading to Quantum Mechanics: LASERS

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### ➤ *Suggested Reading*

1. *Concepts of Modern Physics, Arthur Beiser, Chapter 9.6*
2. *Optical Electronics, A. Yariv*
3. *Course material developed by the department*

### ➤ *Reference Videos*

1. <https://ocw.mit.edu/courses/physics/8-06-quantum-physics-iii-spring-2018/video-lectures/time-dependent-perturbation-theory/l13.3-einsteins-b-and-a-coefficients-determined.-lifetimes-and-selection-rules/>
2. *Unit I Class # 4 Video*

$$R_{Ab} = B_{12} N_1 E(\nu)$$

$$R_{SpEm} = A_{21} N_2$$

$$R_{StEm} = B_{21} N_2 E(\nu)$$

*As the total number of atoms is constant,  
under thermal equilibrium*

$$R_{Ab} = R_{SpEm} + R_{StEm}$$

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

$$(B_{12}N_1 - B_{21}N_2) E(\nu) = A_{21}N_2$$

$$E(\nu) = \frac{A_{21}N_2}{(B_{12}N_1 - B_{21}N_2)} \text{-----} (2)$$

Planck's Expression for Energy Density

$$E(\nu) = \frac{8\pi h\nu^3 / c^3}{\left(e^{h\nu/kT} - 1\right)} \text{-----} (3)$$

$$E(\nu) = \frac{A_{21}/B_{21}}{\left( \frac{B_{12} N_1}{B_{21} N_2} - 1 \right)} \text{----- (4)}$$

*To obtain the above expression we have divided the numerator and denominator of Eq(2) by  $B_{21}N_2$*

*We know*

$$\frac{N_1}{N_2} = e^{h\nu/kT} \text{ (the Boltzman equation)}$$

$$E(\nu) = \frac{\frac{A_{21}}{B_{21}}}{\left( \frac{B_{12}}{B_{21}} e^{h\nu/kT} - 1 \right)} \text{----- (4)}$$

***Planck's Energy density expression***

$$E(\nu) = \frac{8\pi h\nu^3 / c^3}{\left( e^{h\nu/kT} - 1 \right)} \text{----- (3)}$$

*Comparing (3) and (4) we get*

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3} \text{ and } \frac{B_{12}}{B_{21}} = 1 \text{ or } B_{12} = B_{21} = B$$

*So there are only two constants  $A (= A_{21})$  and  $B$  called Einstein's coefficients*

*Planck's Energy density expression*

$$E(\nu) = \frac{\cancel{A}/B}{\left(e^{h\nu/kT} - 1\right)} \text{------(5)}$$

$$\frac{A}{B} = \frac{8\pi h\nu^3}{c^3}$$

### *Check Your Understanding (True/False)*

- 1. The rate of spontaneous emission is the inverse of the life time of the excited state*
- 2. The absorption rate is equal to the sum of the emission rates*
- 3. In equilibrium, the rate of absorption is equal to the rate of stimulated emission*
- 4. The coefficient of absorption is equal to the coefficient of stimulated emission*



# THANK YOU

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