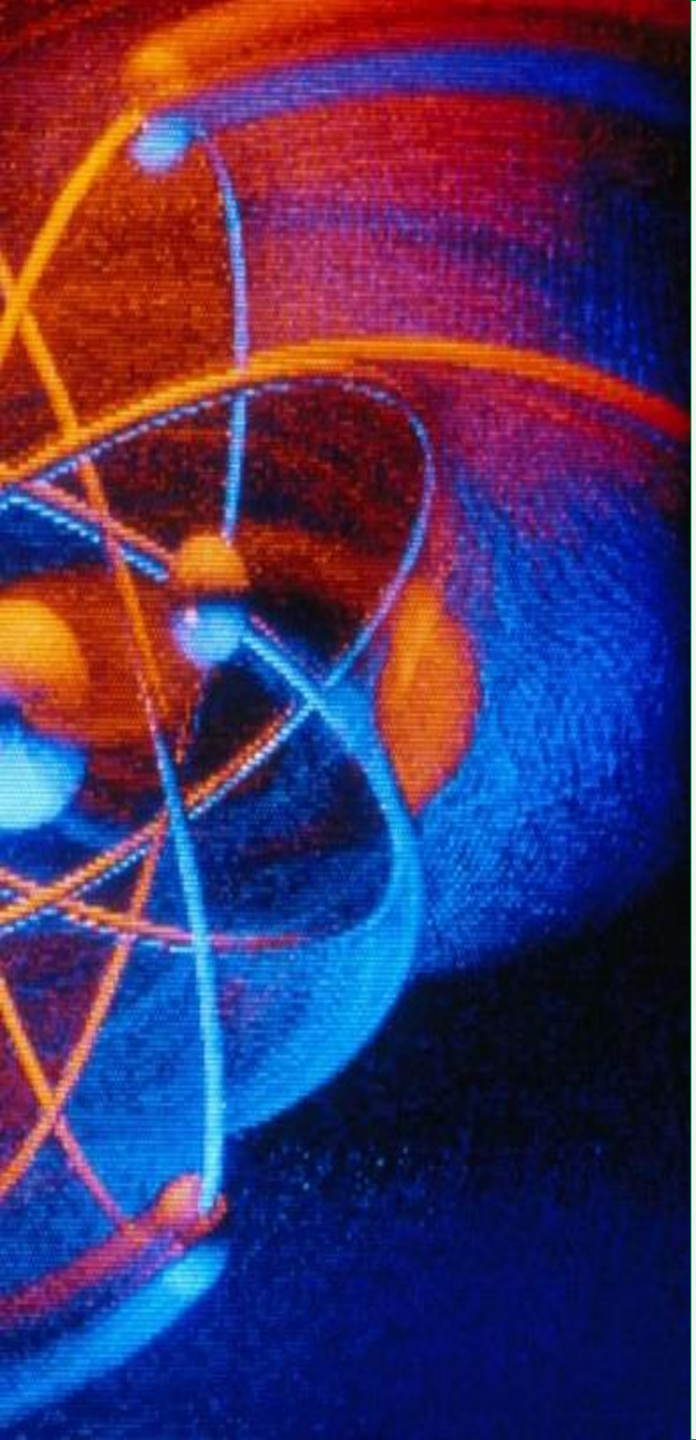


University of Al-Anbar
College of Applied Sciences-Heet
Biophysics Department

Modern Physics-Fourth Stage

Lecture Three

Atomic Physics

Dr. Nabeel F. Lattoofi

The Spin Magnetic Quantum Number m_s

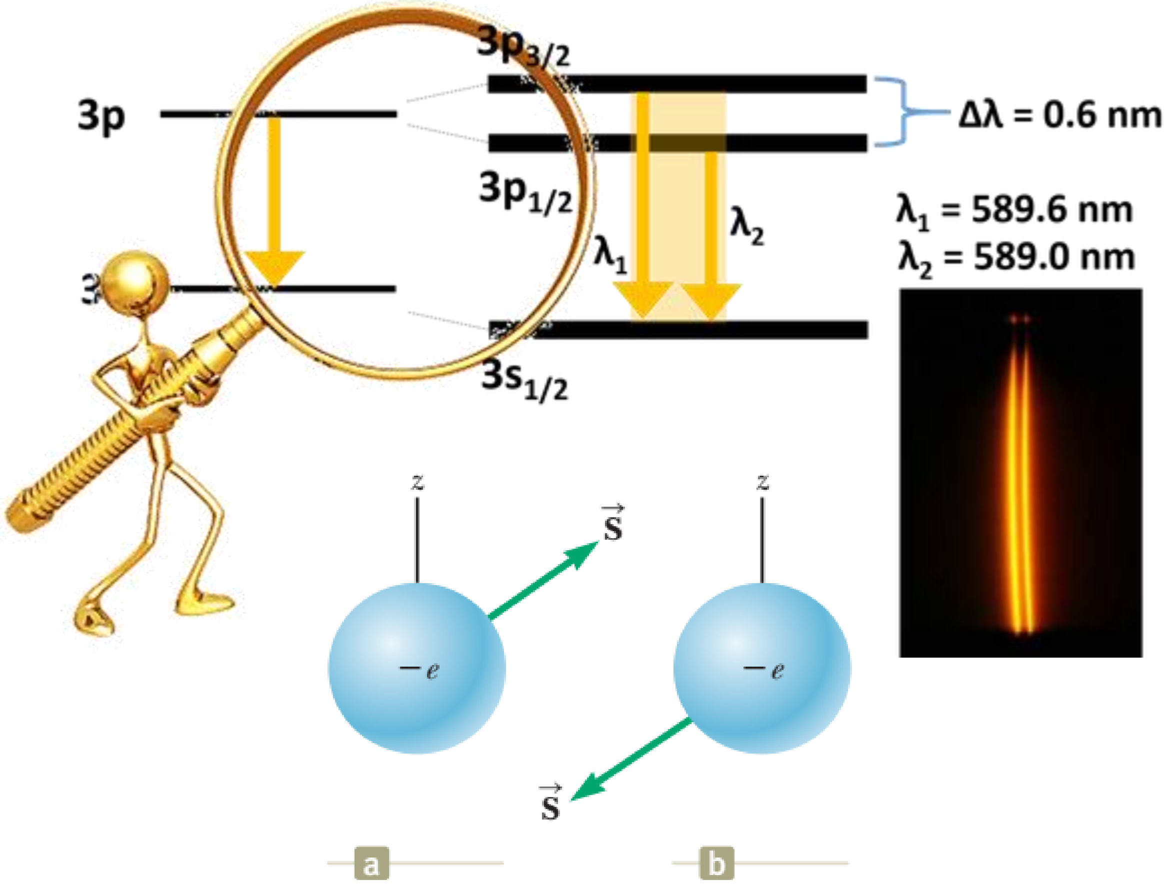
- n, ℓ, and m_ℓ, are generated by applying boundary conditions to solutions of the Schrödinger equation, and we can assign a physical interpretation to each quantum number.

Spin does not come from the Schrödinger equation

sodium dilemma

Samuel Goudsmit (1902–1978) and George Uhlenbeck (1900–1988), following a suggestion made by Austrian physicist Wolfgang Pauli, proposed the spin quantum number.

In the presence of a magnetic field, the energy associated with the electron is slightly different for the two spin directions. This energy difference accounts for the sodium doublet.



Otto and Walter experiment for space quantization

In their experiment, a beam of **silver atoms** sent through a nonuniform magnetic field was split into two discrete components. Then they use **H-atom**.

the total angular momentum of the electron

$$\vec{L} + \vec{S}$$

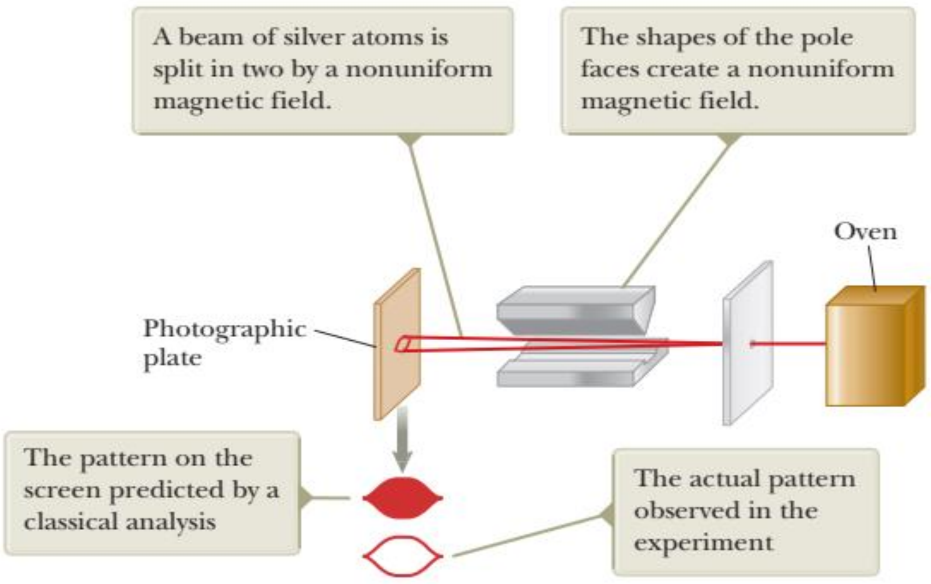
the spin angular momentum $\vec{S}$ for the electron is:

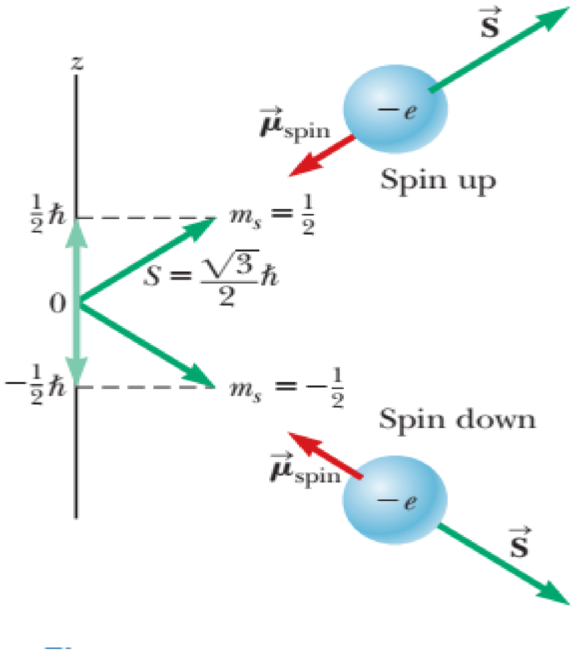
$$S = \sqrt{s(s+1)}\,\hbar = \frac{\sqrt{3}}{2}\hbar$$

spin magnetic quantum number $m_s = \pm\frac{1}{2}$

the *z*-component of spin angular momentum is

$$S_z = m_s\hbar = \pm\tfrac{1}{2}\hbar$$





The Exclusion Principle and the Periodic Table

No two electrons can ever be in the same quantum state; therefore, no two electrons in the same atom can have the same set of quantum numbers.

Table 42.4 Quantum Numbers for the $n = 2$ State of Hydrogen

n	ℓ	m_ℓ	m_s	Subshell	Shell	Number of States in Subshell
2	0	0	$\frac{1}{2}$	2*s*	L	2
2	0	0	$-\frac{1}{2}$			
2	1	1	$\frac{1}{2}$	2*p*	L	6
2	1	1	$-\frac{1}{2}$			
2	1	0	$\frac{1}{2}$			
2	1	0	$-\frac{1}{2}$			
2	1	−1	$\frac{1}{2}$			
2	1	−1	$-\frac{1}{2}$			

Table 42.5 Allowed Quantum States for an Atom Up to $n = 3$

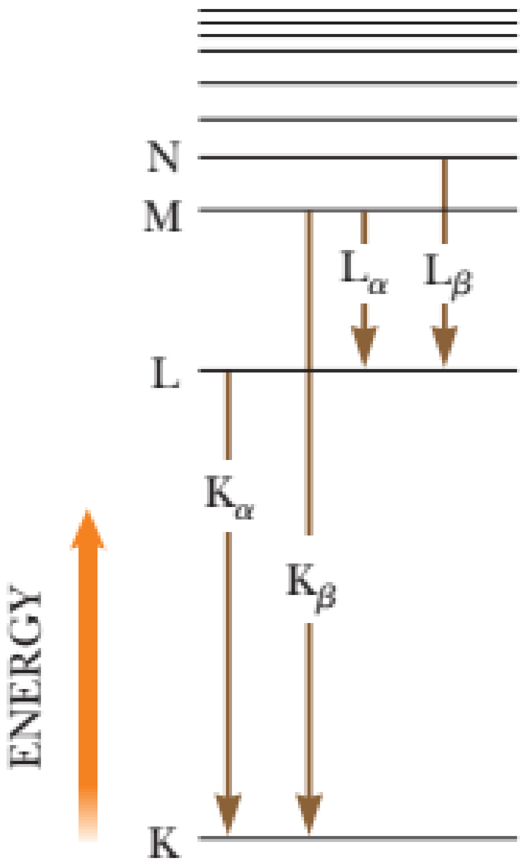
Shell	n	1	2				3								
Subshell	ℓ	0	0	1			0	1			2				
Orbital	m_ℓ	0	0	1	0	−1	0	1	0	−1	2	1	0	−1	−2
	m_s	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓

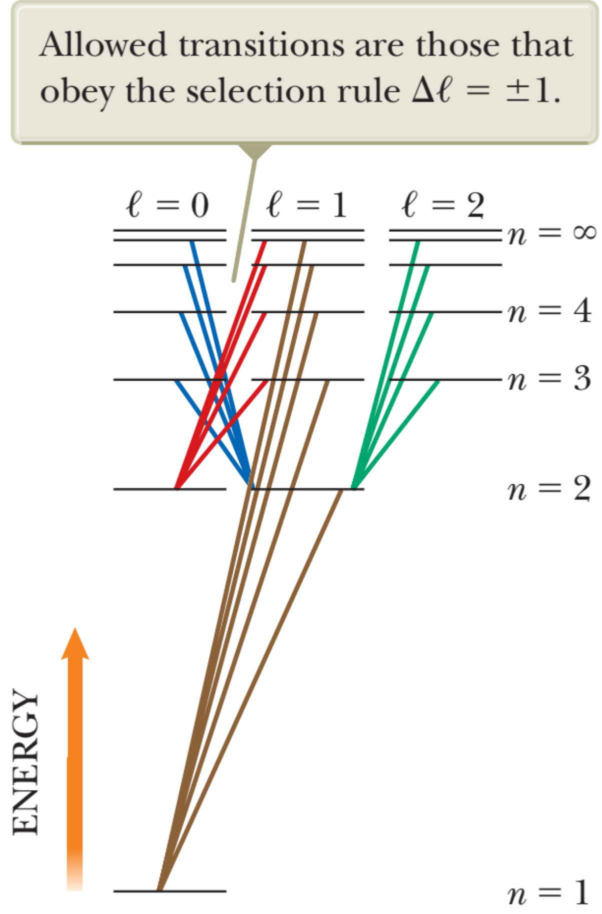
Visible and X-Ray spectra

The **selection rules** for the *allowed transitions* are

$$\Delta\ell = \pm 1 \quad \text{and} \quad \Delta m_\ell = 0, \pm 1$$

Although multielectron atoms cannot be analyzed exactly with either the Bohr model or the Schrödinger equation, we can apply Gauss's law to make some surprisingly accurate estimates of expected x-ray energies and wavelengths as we will see in the next example.





Example 42.5 Estimating the Energy of an X-Ray

Estimate the energy of the characteristic x-ray emitted from a tungsten target when an electron drops from an M shell ($n = 3$ state) to a vacancy in the K shell ($n = 1$ state). The atomic number for tungsten is $Z = 74$.

SOLUTION

Conceptualize Imagine an accelerated electron striking a tungsten atom and ejecting an electron from the K shell ($n = 1$). Subsequently, an electron in the M shell ($n = 3$) drops down to fill the vacancy and the energy difference between the states is emitted as an x-ray photon.

Categorize We estimate the results using equations developed in this section, so we categorize this example as a substitution problem.

Use Equation 42.37 and $Z = 74$ for tungsten to estimate

$$E_K \approx -(74)^2(13.6 \text{ eV}) = -7.4 \times 10^4 \text{ eV}$$

42.5 continued

Use Equation 42.36 and that nine electrons shield the nuclear charge (eight electrons in the $n = 2$ state and one electron in the $n = 1$ state) to estimate the energy of the M shell:

$$E_M \approx -\frac{(13.6 \text{ eV})(74 - 9)^2}{(3)^2} \approx -6.4 \times 10^3 \text{ eV}$$

Find the energy of the emitted x-ray photon:

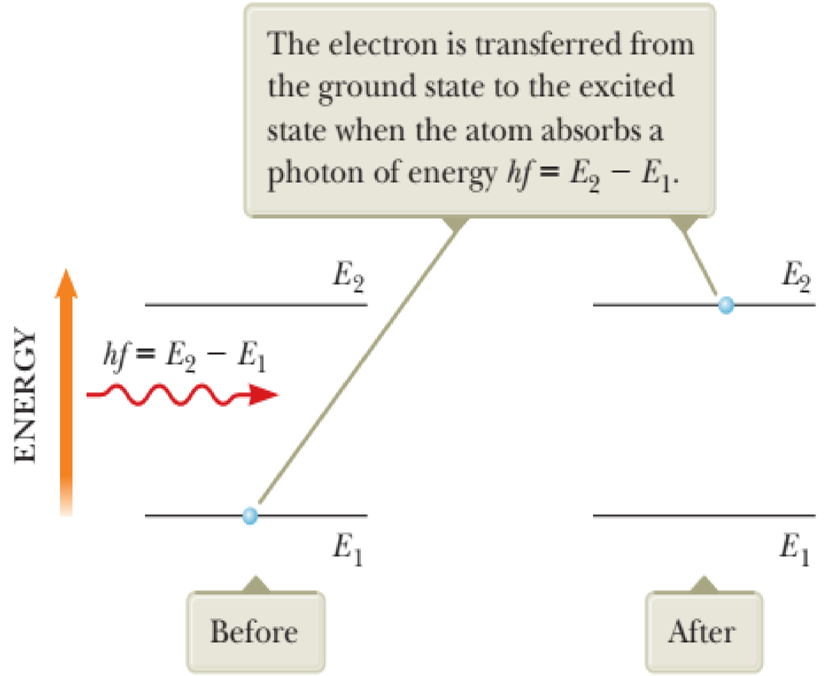
$$hf = E_M - E_K \approx -6.4 \times 10^3 \text{ eV} - (-7.4 \times 10^4 \text{ eV})$$

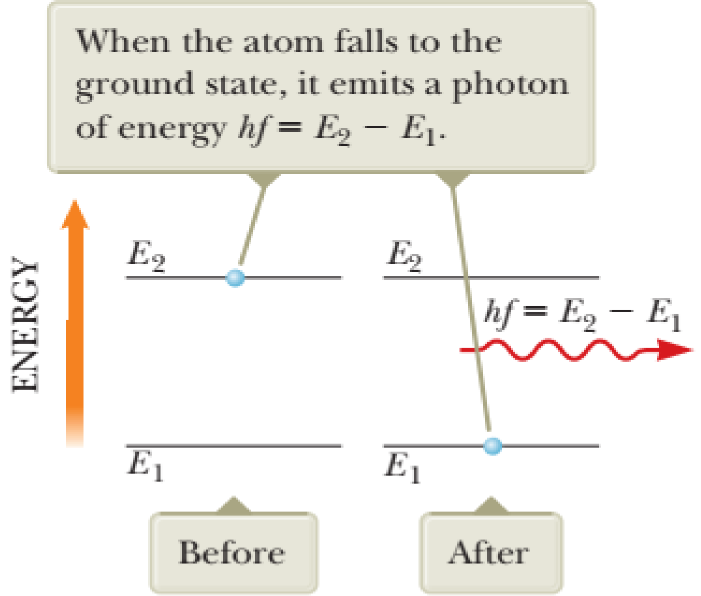
$$\approx 6.8 \times 10^4 \text{ eV} = 68 \text{ keV}$$

Consultation of x-ray tables shows that the M–K transition energies in tungsten vary from 66.9 keV to 67.7 keV, where the range of energies is due to slightly different energy values for states of different ℓ. Therefore, our estimate differs from the midpoint of this experimentally measured range by approximately 1%.

Spontaneous and Stimulated Transitions

- When radiation is incident on the atom, only those photons whose energy *hf* matches the energy separation *ΔE* between two energy levels can be absorbed by the atom. This process is called **stimulated absorption.**
- Once an atom is in an excited state, the excited atom can make a transition back to a lower energy level, emitting a photon. This process is known as **spontaneous emission** because it happens naturally, without requiring an event to trigger the transition. Typically, an atom remains in an excited state for only about 10^{-8} s.
- **stimulated emission** accures If the excited state is a metastable state





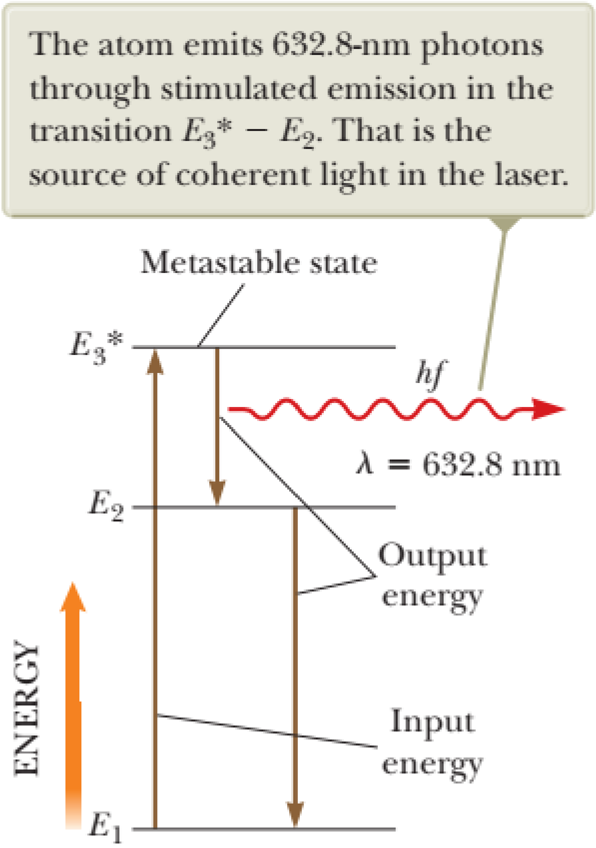
Laser (light Amplification by Stimulated Emission of Radiation)

- Laser light is coherent. The individual rays of light in a laser beam maintain a fixed phase relationship with one another.
- Laser light is monochromatic. Light in a laser beam has a very narrow range of wavelengths.
- Laser light has a small angle of divergence. The beam spreads out very little, even over large distances.
- If the situation can be inverted so that more atoms are in an excited state than in the ground state, however, a net emission of photons can result. Such a condition is called **population inversion**.

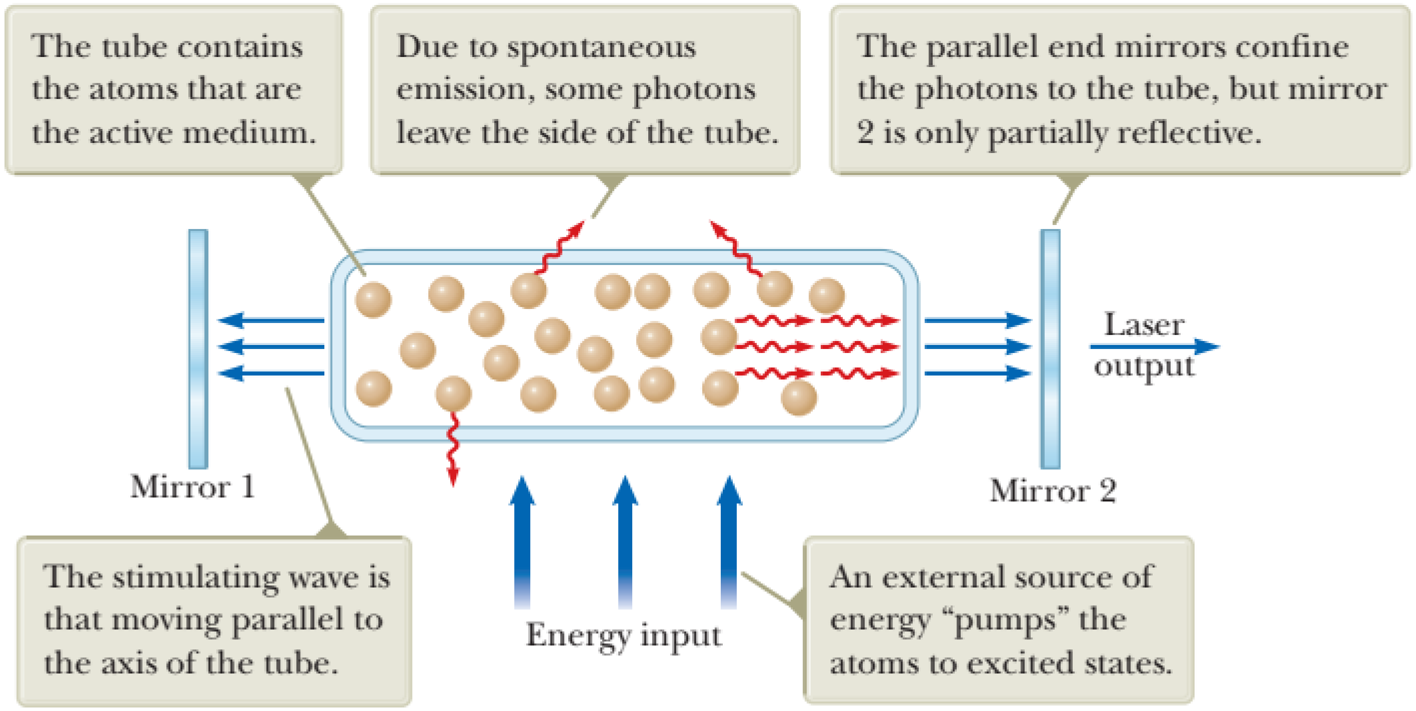
What is the conditions must be satisfied to produce Laser?

- The system must be in a state of population inversion:.
- The excited state of the system must be a metastable state, the population inversion can be established and stimulated emission is likely to occur before spontaneous emission.

- The emitted photons must be confined in the system long enough to enable them to stimulate further emission from other excited atoms. That is achieved by using reflecting mirrors at the ends of the system. One end is made totally reflecting, and the other is partially reflecting. A fraction of the light intensity passes through the partially reflecting end, forming the beam of laser light.

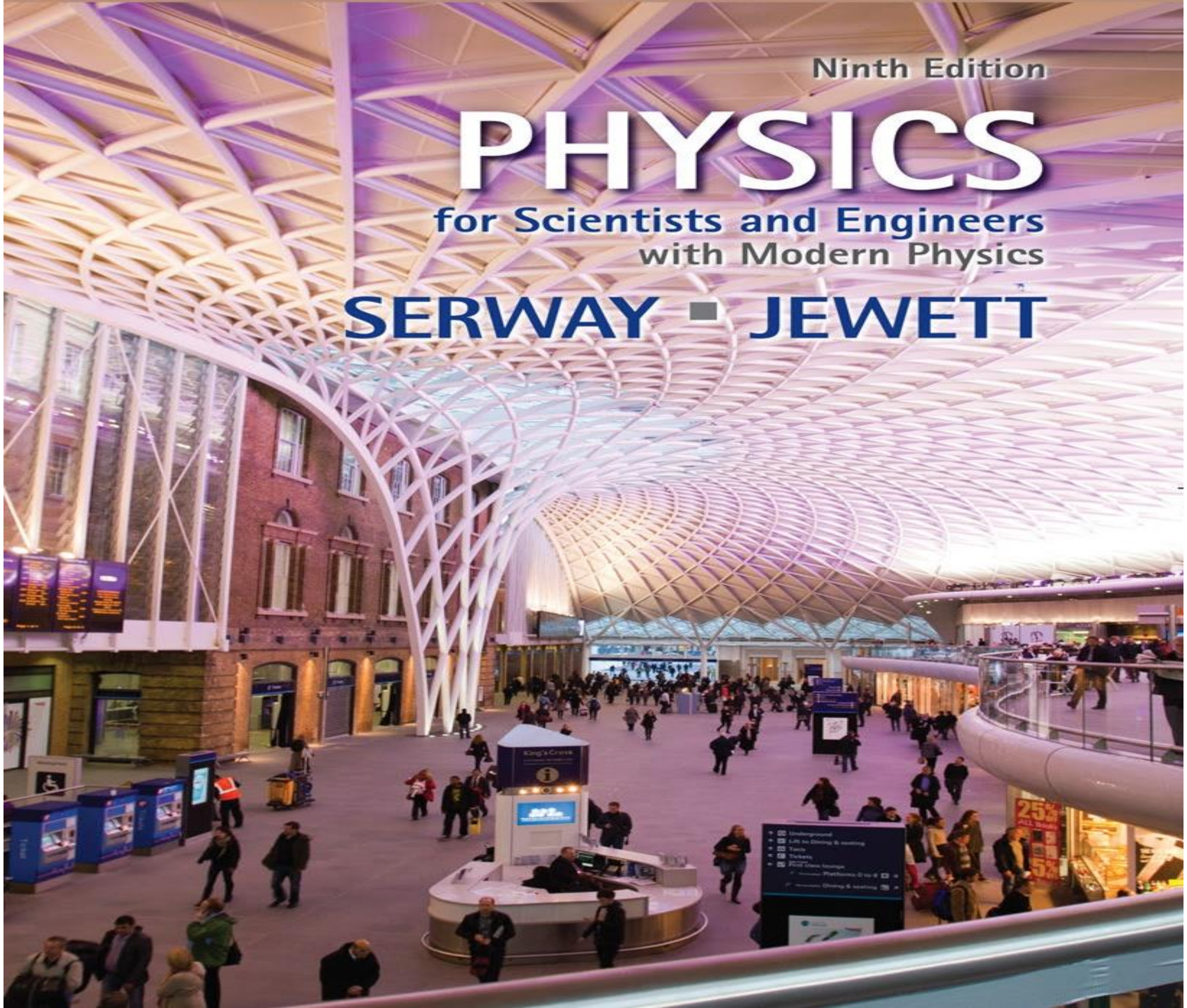


Energy-level diagram for a neon atom in a helium–neon laser.



Thank you
For your Attention

Reference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