Q2. Sources, atoms, and spectra

A. Light source

In its proper reference frame, a point source emits light in the form of a divergent conical beam, with the angular width of 90° (from -45° to +45° with respect to the cone axis). In a reference frame which moves towards the source with an unknown speed v, the angular width of the beam is of only 60° (from -30° to +30° with respect to the same cone axis). The light speed in vacuum is $c = 2.998 \cdot 10^8 \ \frac{m}{s}$.

A	Determine the speed v of the source.	2.50 p.

B. Balmer emission spectrum

The spectral resolving power of a spectrometer is $R = 5 \cdot 10^5$. The spectrometer is used to observe the Balmer series in the emission spectrum of the hydrogen atom (the visible domain).

Note: The possible mechanisms of broadening of the spectral lines (Lorentzian, Gaussian, etc.) will not be considered.

B.1	Express the mathematical definition of the spectral resolving power of the instrument.	0.25 p.

B.2	Determine the highest value for the principal quantum number n of the energy level for which the spectral line emitted by an atom for the transition to the level $n' = 2$ can still be distinctly resolved by the instrument, with respect with its neighbours.	2.25 p.

C. Absorption spectra

The energy levels of an atom are given by $E_n = -\frac{A}{n^2}$, where n is an integer and A is a positive constant. Among the adjacent spectral lines which, at room temperature, the atom can absorb, two have the wavelengths 97.5 nm and 102.8 nm, respectively. The elementary electric charge is $e = 1.602 \cdot 10^{-19}$ C, the speed of light in vacuum is $c = 2.998 \cdot 10^8 \ \frac{m}{s}$, and Planck's constant is $h = 6.626 \cdot 10^{-34}$ J·s.

C.1	Find the values of the quantum numbers n of the energy levels implied in the transitions.	3.00 p.

C.2	Determine the value of the constant A in joule and in electron-volt.	1.50 p.

C.3	Identify the nature of the atom and justify the choice made.	0.50 p.

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Answer sheet

A	Final expression for the speed of the source	Numerical value for the speed of the source	2.50 p.
	$v =$	$v =$	

B.1	$R =$	0.25 p.

B.2	$n =$	2.25 p.

C.1	$n =$	3.00 p.

C.2	in joule	$A =$	1.00 p.
	in electron-volt	$A =$	0.50 p

C.3		0.50 p.