



Particles and Waves (10 points)

General note: if student got the correct answer and the solution is physically and mathematically correct, all the points should be given.

Part A. Quantum particle in a box (1.4 points)

A.1 (0.4 pt.)	Relation between λ_{dB} and p	0.2
	Relation between λ_{dB} and L	0.1
	Correct answer	0.1
A.3 (0.6 pt.)	Relation between $\lambda_{dB}^{(n)}$ and L	0.4
	Correct answer	0.2
A.4 (0.4 pt.)	Relation between photon's energy and wavelength	0.2
	Correct answer	0.2

Part B. Optical properties of molecules (2.1 points)

B.1 (0.8 pt.)	Identify that absorption corresponds to the transition between E_5 and E_6 If any other two levels are used, give 0 pt. for this part, but mathematically correct answer for the chosen energy levels can still be scored with the remaining 0.2 + 0.1 pt.	0.5
	Correct expression	0.2
	Correct numerical value	0.1
B.2 (0.4 pt.)	Correct expression for λ_{Cy3}	0.2
	Correct check	0.1
	Correct numerical value of $\Delta\lambda$	0.1
B.3 (0.7 pt.)	Correct units	0.2
	Correct answer	0.5
B.3 (0.2 pt.)	Correct answer	0.2



Part C. Bose-Einstein condensation (1.5 points)

C.1 (0.4 pt.)	Idea to base estimates on $p^2/(2m) = 3k_B T/2$	0.2
	Correct answer for the momentum	0.1
	Correct calculation of the de Broglie wavelength	0.1
C.2 (0.5 pt.)	Volume per particle V/N as an estimate for ℓ	0.2
	Correct answer for the distance ℓ	0.1
	Correct answer for the critical temperature T_c	0.2
C.3 (0.6 pt.)	Correct expression for n_c	0.2
	Correct numerical value for the density n_c	0.1
	Correct expression for n_0	0.2
	Correct numerical value for the ratio n_0/n_c	0.1

Part D. Three-beam optical lattices (5.0 points)

D.1 (1.4 pt.)	Individual laser fields summed	0.2
	Correct squaring and averaging	0.6
	Correct answer for $V(\vec{r})$	0.3
	Vectors \vec{b} identified as differences of \vec{k} (in any order)	0.3
D.2 (0.5 pt.)	Convincing argument	0.5
D.3 (1.2 pt.)	Correct calculation of $V_X(x)$	0.3
	Correct calculation of $V_Y(y)$	0.3
	Six inequivalent extrema identified (0.1 pt per each)	0.6
D.4 (0.8 pt.)	Correct calculation of the lattice constant	0.4
	Existence of 6 equivalent minima identified	0.2
	Correct identification of the positions	0.2
D.5 (1.1 pt.)	Correct description of force on the outer electron	0.4
	Screening by core electrons overlooked	-0.1
	Correct expression for the angular momentum	0.2
	Correct calculation of the principal quantum number n	0.4
	Correct numerical value for n	0.1