

A COURSE SYLLABUS – DOCTORAL SCHOOL
REGARDING THE QUALIFICATION CYCLE FROM 2024/2025 TO 2027/2028

GENERAL INFORMATION ABOUT COURSE	
Course title	WORKSHOPS WITH AN EXPERT Scientific focus: Why forbidden molecular transitions radiate: spin–orbit mixing, photon emission and the lifetime of CO
Name of the unit running the course	Doctoral School at University of Rzeszów
Type of course (<i>obligatory, optional</i>)	<i>obligatory</i>
Year and semester of studies	Year III / semester V
Discipline	PHYSICS
Language of Course	English
Name of Course coordinator	Prof Roman Pasechnik
Name of Course lecturer	Prof Roman Pasechnik
Prerequisites	Basic linear algebra and the Schrödinger equation. Kets, spin operators, oscillator quanta, perturbation amplitudes and rate conventions are introduced as needed. Familiarity with molecular spectroscopic labels is helpful. No prior quantum field theory course is required.
BRIEF DESCRIPTION OF COURSE (100-200 words)	
How can the same interaction shift a molecular energy level and enable a spin-forbidden decay, and what can line positions tell us about a radiative lifetime? The workshop connects this question to deperturbation of the $a^3\Pi$ state of neutral CO. It derives the electric-dipole spin selection rule, introduces microscopic spin–orbit mixing and solves a two-state mixing problem exactly. Quantization of the radiation field and time-dependent perturbation theory then give an absolute spontaneous-emission rate. A conditional relation between level shifts and radiative rates is established for one borrowing state. Extending the transition amplitude to several virtual pathways reveals interference and the limitations of inferring intensities from energies alone. The final comparison with level-resolved CO lifetime studies distinguishes conclusions of the analytic model from the molecular inputs required for quantitative spectroscopy.	

COURSE LEARNING OUTCOMES AND METHODS OF EVALUATING LEARNING OUTCOMES				
Learning outcome	The description of the learning outcome defined for the course	Relation to the degree programme outcomes (symbol)	Learning Format (Lectures, classes,...)	Method of assessment of learning outcomes (e.g. test, oral exam, written exam, project,...)
Knowledge (no.)	(Knows and understands)			
P8S_WG2	Possesses knowledge of research directions and current achievements, including international work, in spin-orbit mixing, effective transition operators, quantized radiation and radiative observables in molecular spectroscopy, and understands their connection to the doctoral student's research interests.	P8S_WG	Individual workshop and discussion	Written report and scientific discussion
P8S_WK1	Knows and understands how technological development influences scientific and societal progress in molecular spectroscopy and radiative diagnostics. Can discuss the resulting consequences for the wider world, including the capabilities and limitations of the methods considered.	P8S_WK	Individual workshop and discussion	Discussion of technological context and wider implications
Skills (no.)	(Able to)			
P8S_UW1	Based on interdisciplinary knowledge, the doctoral student is able to identify and solve research problems related to the topic of scientific research conducted in the discipline of physical sciences, define research goals, formulate hypotheses and the subject of scientific research, develop research methods, techniques and tools, and draw constructive conclusions based on research results.	P8S_UW	Individual workshop and discussion	Report derivations and interpretation

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P8S_UK6	Using a foreign language at least at the B2 level of the Common European Framework of Reference for Languages, a doctoral student is able to present research results, take part in discussions and actively participate in scientific and professional debates both at the national and international level.	P8S_UK	Individual workshop and discussion	Scientific discussion and report in English
P8S_UU1	A doctoral student is able to independently acquire and update knowledge, develop analytical skills based on current interdisciplinary scientific achievements, and inspire others to conduct research and development activities.	P8S_UU	Individual workshop and discussion	Report sources and independent reconstruction
P8S_UU2	A doctoral student is able to share his or her knowledge, thanks to his or her extensive interdisciplinary knowledge, he or she is able to plan and implement interesting classes, and is also able to inspire others by supporting the learning process and by using modern and innovative teaching methods and tools.	P8S_UU	Individual workshop and discussion	Structured explanation of a derivation in the report and discussion
P8S_UU3	Thanks to the continuous learning process, the doctoral student updates his/her interdisciplinary knowledge, improves his/her scientific competences and plans his/her own development and the development of others.	P8S_UU	Individual workshop and discussion	Discussion of limitations and further study

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Social competence (no.)	(Ready to)			
P8S_KK1	The doctoral student is ready to critically evaluate scientific achievements in the chosen scientific discipline of physical sciences, taking into account current research trends and quality standards of scientific research in the field of physics	P8S_KK	Individual workshop and discussion	Critical evaluation of sources in the report
P8S_KK2	Is ready to critically evaluate his/her own research contribution to scientific achievements in the chosen scientific discipline of physics, in the area of his/her interests and research.	P8S_KK	Individual workshop and discussion	Attribution of reproduced results and appraisal of the student's own reasoning
P8S_KK3	Is ready to solve theoretical and practical problems using his/her knowledge of exact and natural sciences within the discipline of physical sciences and related disciplines, in particular those relating to the doctoral student's scientific interests.	P8S_KK	Individual workshop and discussion	Report reasoning and scientific discussion

A fail applies if no report is submitted or the work does not demonstrate these essential outcomes. The submission date is communicated by the lecturer.

TOTAL PhD STUDENT WORKLOAD REQUIRED TO ACHIEVE THE INTENDED LEARNING OUTCOMES – NUMBER OF HOURS AND ECTS CREDITS	
Activity	Number of hours
Scheduled course contact hours	5 hours
Other contact hours involving the teacher (consultation hours, examinations)	1 hour
Non-contact hours – student's own work (preparation for classes or examinations, project, etc.)	24 hours
Total number of hours	30 hours
Total number of ECTS credits	1 ECTS
INSTRUCTIONAL MATERIALS	
Compulsory literature:	1. J. J. Gilijamse et al., The radiative lifetime of metastable CO ($a^3\Pi, v = 0$), Journal of Chemical Physics 127, 221102 (2007). DOI: 10.1063/1.2813888; arXiv:0710.2240. Selected results on level-specific lifetimes and single- versus multiple-singlet borrowing. 2. N. S. Mosyagin et al., Ab initio relativistic treatment of the $a^3\Pi-X^1\Sigma^+$, $a'^3\Sigma^+-X^1\Sigma^+$ and $A^1\Pi-X^1\Sigma^+$ systems of the CO molecule, Journal of Quantitative Spectroscopy and Radiative Transfer 263, 107532 (2021). DOI: 10.1016/j.jqsrt.2021.107532; arXiv:2010.08849 (preprint title differs). Selected transition moments and level-resolved lifetimes.
Complementary literature:	1. P. A. M. Dirac, The Quantum Theory of the Emission and Absorption of Radiation, Proceedings of the Royal Society of London A 114, 243–265 (1927). DOI: 10.1098/rspa.1927.0039. Historical primary source for quantized-radiation emission theory. 2. C. C. Gerry and P. L. Knight, Introductory Quantum Optics, Cambridge University Press (2005). Supplementary background on radiation-field quantization and atom–field interaction. ISBN: 9780521820356.

ONE ECTS CREDIT CORRESPONDS TO 25–30 HOURS OF TOTAL DOCTORAL-STUDENT WORKLOAD.

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Date and signature of the Course lecturer

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Approved by the Head of the Department or an authorised person