Syllabus, Texas Tech Fall Semester, 2022

PHYS-5300-19, Special Topics
Physical Sciences at the Nanometer-Scale, and Quantum Sensor Design

Instructor: Robert V. Duncan, Ph.D.
President's Distinguished Chair in Physics

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Meets 9:30 – 10:50 AM Tuesdays and Thursdays, Hybrid format
On-line ZOOM Meeting at:
https://texastech.zoom.us/j/93248342880?pwd=UElsQ1ZiZzA4NFFxSGlBSGJtRUpTZz09

Office Hours will be held on TR immediately following class, or by appointment
In-person lab meetings will be held at the locations listed by date in the detailed class plan below.

Study materials will be posted by date on the TTU Physics and Astronomy CEES Web page under the 'Instruction' tab page at: https://www.depts.ttu.edu/phas/cees/ If you have not done so already, I recommend enrolling in the Solid State Physics Course that is also offered this semester. This is not a requirement, but a useful recommendation.

We will introduce methods of advanced materials properties measurement, and nanomaterials design, within this course. We will also discuss the principles of physics and chemistry at the nanometer scale, and the nature of macroscopic quantum coherence in materials, such as superconductors, superfluids, quantum dot arrays, and in Bose-Einstein Condensates (BEC).

Grading: Students will be asked to prepare a term paper in one of the topical areas described below, based upon their class notes, publications that we will discuss in class, and lab results that they obtain in this class. The student's grade will be based upon this term paper (75%), on laboratory and class attendance and participation (25%), These topics include:

1) Properties of materials, and engineering principles, as a function of size
2) Multi-scale imaging, AI detection of emergent phenomena, and quantum dot arrays
3) Magnetic properties of materials, nanomagnets, and spintronics
4) Fabrication and characterization of nanomaterials
5) Nuclear nanotechnology, fission / fusion fragment nanoparticles, and applications
6) Quantum coherence, superconductivity, superfluidity, BEC
7) Quantum dot design principles for quantum sensors

In the lab, students will learn to operate the Quantum Design 'DynaCool' Physical Properties Measurement System (PPMS), and various electron microscopes, and the Zeiss 540 Crossbeam Focused Ion Beam (FIB) system to fabricate quantum dot arrays, and to study emergent structures at the nanometer level. We will also conduct laboratory demonstrations and various other techniques that will be useful for the students to understand as they are introduced to this new field of research.

Required and Recommended Syllabus Statements are listed below. Contact your instructor if you have any questions regarding these statements.

ADA STATEMENT:

Any student who, because of a disability, may require special arrangements in order to meet the course requirements should contact the instructor as soon as possible to make any necessary arrangements. Students should present appropriate verification from Student Disability Services during the instructor's office hours. Please note: instructors are not allowed to provide classroom accommodations to a student until appropriate verification from Student Disability Services has been provided. For additional information, please contact Student Disability Services in West Hall or call 806-742-2405.

ACADEMIC INTEGRITY STATEMENT:

Academic integrity is taking responsibility for one's own class and/or course work, being individually accountable, and demonstrating intellectual honesty and ethical behavior. Academic integrity is a personal choice to abide by the standards of intellectual honesty and responsibility. Because education is a shared effort to achieve learning through the exchange of ideas, students, faculty, and staff have the collective responsibility to build mutual trust and respect. Ethical behavior and independent thought are essential for the highest level of academic achievement, which then must be measured. Academic achievement includes scholarship, teaching, and learning, all of which are shared endeavors. Grades are a device used to quantify the successful accumulation of knowledge through learning. Adhering to the standards of academic integrity ensures grades are earned honestly. Academic

integrity is the foundation upon which students, faculty, and staff build their educational and professional careers. [Texas Tech University ("University") Quality Enhancement Plan, Academic Integrity Task Force, 2010].

RELIGIOUS HOLY DAY STATEMENT:

"Religious holy day" means a holy day observed by a religion whose places of worship are exempt from property taxation under Texas Tax Code §11.20. A student who intends to observe a religious holy day should make that intention known in writing to the instructor prior to the absence. A student who is absent from classes for the observance of a religious holy day shall be allowed to take an examination or complete an assignment scheduled for that day within a reasonable time after the absence. A student who is excused under section 2 may not be penalized for the absence; however, the instructor may respond appropriately if the student fails to complete the assignment satisfactorily.

COVID-19 STATEMENT

The University will continue to monitor CDC, State, and TTU System guidelines concerning COVID-19. Any changes affecting class policies or temporary changes to delivery modality will be in accordance with those guidelines and announced as soon as possible. Students will not be required to purchase specialized technology to support a temporary course modality change, though students are expected to have access to a computer to access course content and course-specific messaging as needed.

If you test positive for COVID-19, report your positive test through TTU's reporting system: https://www.depts.ttu.edu/communications/emergency/coronavirus/. Once you report a positive test, the portal will automatically generate a letter that you can distribute to your professors and instructors. *Here is the COVID-19 resource page:* https://www.depts.ttu.edu/communications/emergency/coronavirus/

DISCRIMINATION, HARASSMENT, AND SEXUAL VIOLENCE STATEMENT:

Texas Tech University is committed to providing and strengthening an educational, working, and living environment where students, faculty, staff, and visitors are free from gender and/or sex discrimination of any kind. Sexual assault, discrimination, harassment, and other Title IX violations are not tolerated by the University. Report any incidents to the Office for Student Rights & Resolution, (806)-742-SAFE (7233) or file a report online at titleix.ttu.edu/students. Faculty and staff members at TTU are committed to connecting you to resources on campus. Some of these available resources are: TTU Student Counseling Center, 806- 742-3674, https://www.depts.ttu.edu/scc/(Provides confidential support on campus.) TTU 24-hour Crisis Helpline, 806-742-5555, (Assists students who are experiencing a mental health or interpersonal violence crisis. If you call the helpline, you will speak with a mental health counselor.) Voice of Hope Lubbock Rape Crisis Center, 806-763-7273, voiceofhopelubbock.org (24-hour hotline that provides support for survivors of sexual violence.) The Risk, Intervention, Safety and Education (RISE) Office, 806-742-2110, https://www.depts.ttu.edu/rise/ (Provides a range of resources and support options focused on prevention education and student wellness.) Texas Tech Police Department, 806-742-3931, http://www.depts.ttu.edu/ttpd/(To report criminal activity that occurs on or near Texas Tech campus.)

CIVILITY IN THE CLASSROOM STATEMENT:

Texas Tech University is a community of faculty, students, and staff that enjoys an expectation of cooperation, professionalism, and civility during the conduct of all forms of university business, including the conduct of student–student and student–faculty interactions in and out of the

classroom. Further, the classroom is a setting in which an exchange of ideas and creative thinking should be encouraged and where intellectual growth and development are fostered. Students who disrupt this classroom mission by rude, sarcastic, threatening, abusive or obscene language and/or behavior will be subject to appropriate sanctions according to university policy. Likewise, faculty members are expected to maintain the highest standards of professionalism in all interactions with all constituents of the university (www.depts.ttu.edu/ethics/matadorchallenge/ethicalprinciples.php).

PLAGIARISM STATEMENT:

Texas Tech University expects students to "understand the principles of academic integrity and abide by them in all class and/or course work at the University" (OP 34.12.5). Plagiarism is a form of academic misconduct that involves (1) the representation of words, ideas, illustrations, structure, computer code, other expression, or media of another as one's own and/or failing to properly cite direct, paraphrased, or summarized materials; or (2) self-plagiarism, which involves the submission of the same academic work more than once without the prior permission of the instructor and/or failure to correctly cite previous work written by the same student. This video, retrieved from the University of Kansas Libraries website, provides an example of a plagiarism definition as well as examples of plagiarism and how to avoid it. Please review Section B of the TTU Student Handbook for more information related to other forms of academic misconduct, and contact your instructor if you have questions about plagiarism or other academic concerns in your courses. To learn more about the importance of academic integrity and practical tips for avoiding plagiarism, explore the resources provided by the TTU Library and the School of Law.

LGBTQIA SUPPORT STATEMENT:

Office of LGBTQIA, Student Union Building Room 201, www.lgbtqia.ttu.edu, 806.742.5433

Within the Center for Campus Life, the Office serves the Texas Tech community through facilitation and leadership of programming and

advocacy efforts. This work is aimed at strengthening the lesbian, gay, bisexual, transgender, queer, intersex, and asexual (LGBTQIA) community and sustaining an inclusive campus that welcomes people of all sexual orientations, gender identities, and gender expressions.

STATEMENT ABOUT FOOD INSECURITY:

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. Furthermore, please notify the professor if you are comfortable in doing so. The TTU Food Pantry is in Doak Hall 117. Please visit the website for hours of operation at https://www.depts.ttu.edu/dos/foodpantry.php.

Daily Course Plan

This detailed plan is subject to change with advanced notice. The locations in the table below will be more precisely defined ahead of the class meetings.

Date	Location	Topic
8/25	ON-LINE	Introduction to the class, grading, laboratory safety is paramount High-level introduction to nanoscience and quantum sensing How are things different at the nanometer-scale? Bottom-up and top-down nanofabrication technology Discuss: Richard Feynman, “Plenty of Room at the Bottom” (1959)
8/30	ON-LINE	More on size dependence in physics Single-electron charging of quantum dots – setting the scale Intuition and quantum mechanics
9/01	ON-LINE	Introduction to the production of nanoparticles Safety in working with nanomaterials
9/06	Reese B61	Techniques for producing nanoparticles in the lab Nanoparticle synthesis and experimentation
9/08	Reese B61	Follow-up on nanoparticle synthesis More on instrumentation
9/13	Imaging C	Imaging nanoparticles with TEM Experimental technique and instrumentation – diagnostics
9/15	ON-LINE	Quantum dot arrays and applications Quantum coherence in nanodot arrays Discuss: Lawrie, et al., “Quantum Dot Arrays in Si and Ge”

9/20	Imaging C	Introduction to the Zeiss Crossbeam 540 SEM and FIB Examples of sample preparation and fabrication Introduction to Hitachi 3400
9/22	Imaging C	More SEM / FIB lab Design and fabrication of nanodot arrays in Pt
9/27	Imaging C	Continuation on nanodot array fabrication
9/29	Reese 61	Wire bonding Demonstration: Muons, catalyzed fusion, and muon tomography
10/4	ON-LINE	Nuclear measurements – alpha, beta, gamma and spectroscopy Nano-nuclear fuels & fission / fusion fragment (FFF) nuclear rockets Nanoparticle nuclear energy Nuclear laboratory safety
10/6	Warehouse	Nuclear measurements
10/11	ESB 153	Tritium assays / P&E Quantulus instrument Results of irradiations at the MU Research Reactor and Cyclotron (MURR)
10/13	ON-LINE	Mossbauer effect and nuclear spectroscopy Introduction to Quantum Nucleonics Lattice magnon excitations to control nuclear quantum dynamics
10/18	ON-LINE	Physical properties of materials, theory and experiment Resistance, magneto-resistance, susceptibility, heat capacity, others Quantum Designs Physical Properties Measurement System (PPMS) Introduction to narrow-banding / phase-lock amplification
10/20	Science 118	Measurements of magnetoresistance, Hall conductance, susceptibility, and other physical properties using the Quantum Designs PPMS Properties of Cu, Fe, Pt and Pd: Differences and similarities
10/25	Science 118	Continuation from above Hall Effect Measurements
10/27	Science 118	Continuation from above Specific heat measurements Custom measurements using the PPMS
11/01	Science 118	Measurements of the Pt quantum dot array using the PPMS
11/03	ON-LINE	Magnetic materials properties Mean-field theory, exchange, and critical phenomena Magnetic susceptibility measurements with coils & SQUIDs
11/08	ON-LINE	Magnetic inductance and kinetic inductance Introduction to spintronics
11/10	Science 118	Superconductivity: Macroscopic quantum coherence Measuring magnetic and thermal properties of superconductors Magnetic susceptibility and specific heat Competition between superconductivity and magnetism High-Temperature superconductors
11/15	ON-LINE	Quantum sensing using Josephson technology & SIS quasiparticle mixers

11/17	ESB 153	Macroscopic quantum coherence in superfluids, second sound Self-organized criticality (SOC) near the superfluid transition Bose-Einstein Condensation (BEC)
11/22	ON-LINE	Macroscopic quantum circuits, SLUGS, SQUIDS, and 'SHIGS' Fundamental physics measurements using these techniques
11/24	@Home	Thanksgiving Holiday, no classes
11/29	ESB 153	Superconductive and superfluid physics laboratory experiments Other techniques in experimental low-temperature physics
12/01	ESB 153	Superconducting magnets, Josephson junctions, and quantum sensors
12/06	ON-LINE	Class summary and editing / publication plans