Faculty of Physics, Lomonosov Moscow State University

Advanced Quantum Field Theory: Modern Applications in HEP, Astro & Cond-Mat

Instructor: assist. prof., Dr. **Oleg Kharlanov**

Term 1 Examination Syllabus (Spring 2016)

1. London dispersion forces between hydrogen atoms: second-quantized formulation, electric dipole polarizability, calculation of the force.

2. Second quantization of a real massless scalar field in a compact domain. Vacuum energy as a formal series over 1-particle states and via point-splitting. Point-split stress tensor and the Green's function. Casimir tension via the 'energy' T_{00} and the 'pressure' T_{nn}.

3. Casimir effect for a massless scalar field between two plates with the Dirichlet boundary conditions: one-particle states between the plates, explicit energy regularization and renormalization using the smooth cutoff.

4. Electromagnetic Casimir effect between two conducting plates: second quantization, vacuum energy as a series over one-photon energies, one-particle states in the Coulomb gauge. Zeta function of $-\nabla^2$ defined on 1-photon wavefunctions between the plates and the Casimir energy.

5. Casimir tension of a massless scalar field between two plates with the Dirichlet boundary conditions using the Green's function technique (the 'pressure' T_{nn} version). The normal-normal component of the stress tensor via the Fourier image of the Green's function, the Wick rotation.

6. Casimir tension for a massless scalar field between a resting and a uniformly moving plate. The Green's function in terms of the reflection operators. Casimir energy renormalization.

7. The Dynamical Casimir Effect for a massless scalar field and an arbitrarily moving 'mirror' in $D=1+1$. Functional equation on the conformal map 'stopping' the mirror. Second-quantized field operator. The point-split stress tensor and regularization of its v.e.v.'s. Mirror energy loss per 1 second due to the Casimir effect.

8. Quantization of the $D=1+1$ φ^4 theory around a classical solution in the weak-coupling approximation. Vacuum energy (a formal series) and the second-quantized field operator of the excitations. Kink mass renormalization via normal ordering.

9. Photon splitting in a strong external magnetic field. Kinematic considerations. Tensor structure of the matrix elements, hexagon diagram and the Heisenberg–Euler effective Lagrangian. Matrix element for photon splitting and the splitting length (in brief).

10. Neutrino oscillations in dense media. Density matrix description, forward scattering on the neutral dense *e*/*p*/*n* background medium and the effect of neutrino self-action on the oscillations. The effective Hamiltonian for collective neutrino oscillations.

11. Dynamical Lorentz violation in the Axion-Wess–Zumino model. Photons in a constant axion gradient background, 1-loop effective potential for axions (a photon loop). UV completion of the theory and the renormalized potential. Dynamical symmetry violation, critical coupling.