STUDENT GUIDE FOR GRADUATE STUDIES
ENGINEERING PHYSICS DEPARTMENT
(February 2024)

Welcome to the graduate program of the Engineering Physics Department! Unlike undergraduate studies, graduate studies offer you the exciting opportunity to have a strong impact on exceptional socio-economic challenges through state-of-the-art research and discovery.

To give you a feeling of community in our department and to introduce you to the vast world of research in engineering physics, we have created a series of seminars. There you will discover new research areas at the cutting-edge of science and technology and meet and interact with world-recognized researchers. In the doctoral program, the comprehensive exam will give you an opportunity to consolidate the basic principles of engineering physics within an organized foundation. This will help you to move forward smoothly and efficiently in research projects.

This document details the supporting tools we offer for preparation for the comprehensive exam. It also provides information on the procedures for submitting and presenting a dissertation for the Masters degree.

The Engineering Physics Department is delighted to have you as a member. We hope that this important stage of your training will be successful and will represent a solid platform for your personal and professional development.

Good luck!

1. Course PHS6910 – Engineering Physics Seminars

Students registered in the Masters and Doctoral Research programs must follow the course PHS6910 – Engineering Physics Seminars.

This course takes place over the course of a year and includes the following activities:

1. Around ten (10) departmental seminars. These seminars are on Thursday mornings at 11:00. There are usually five (5) seminars during the fall and five (5) during the winter.
2. Meetings with guest speakers. These allow students to chat and interact with the speakers.
3. Participation in seminars is mandatory and will determine your course grade. Only justified absences are allowed.

Since this course runs over a year, there are two possible paths. The first so-called *normal* path should be suitable for the majority of Masters and Doctoral students. **This requires students to register for this course exclusively in the fall**. For students whose study plan does not allow this course to start during the fall for exceptional reasons, a *special* path is offered.

Following the first trimester, the grade IV (incomplete) will appear on the transcript. The student will then have to complete the requirements listed above in the next trimester, otherwise the grade F (failure) will appear on the transcript.

For all special circumstances, you are invited to contact the person responsible for this course or the Graduate Studies Coordinator as soon as possible.

Path	Beginning of activities and trimester registration	End of activities	Activities			
			Fall	Winter	Summer	Fall
Normal	Fall	Winter	- Workshop CAP (September) - Participation in seminars and meetings	- Participation in seminars and meetings - Workshop CAP (April)		
Special	Winter	Fall		- Participation in seminars and meetings		- Workshop CAP (September) - Participation in seminars and meetings - Workshop CAP (December)

2. General comprehensive exam

The general comprehensive exam consists of a written and an oral part. The written exam evaluates the candidate's general level of knowledge and the oral exam verifies the ability to synthesize and analyze. Note that this exam is not a selection method, it is a tool to ensure that the candidate has adequate training and the ability to make an original contribution during her/his scientific research work.

To meet the requirements of the comprehensive exam, the candidate must take both the written and oral parts of the exam before the end of the 4th trimester. If at the end of the 5th trimester the exam has still not been passed, the student will no longer be authorized to continue, and her/his candidacy will normally be cancelled.

2.1 Written exam in Engineering Physics

- The written exam is usually offered twice a year: during the months of November and June. The exact date is announced about twelve (12) weeks before the exam.
- The written exam lasts four (4) hours. No documentation is allowed. A pocket calculator (non-programmable) is allowed.
- It includes eight (8) questions at the undergraduate level on the following subjects:

  - Mechanics (1)
  - Quantum mechanics (1)
  - Optics (2)
  - Electricity and magnetism (1)
  - Solid-state physics (2)
  - Statistical physics (1)

- The expected level of understanding corresponds to that of a good third- or fourth-year bachelor student. Typically, a question takes 30 minutes to answer.
- The student must provide answers to six (6) questions that must be chosen from the eight (8) questions proposed. The grade is 20 points per question and the passing grade is 50 out of a maximum of 120 points.
- A candidate whose training is not engineering physics (or the equivalent) may benefit from two additional questions on a subject related to her/his bachelor training. However, in order to pass the exam, a minimum of 25 points must be obtained for the engineering physics questions mentioned above.
- Several old exams are available at https://www.polymtl.ca/phys/programmes-détudes/études-supérieures/banque-examens

- The coordinator of the Graduate Studies Program (CPES) communicates the result directly to the candidate and to her/his research supervisor approximately two weeks after the date of the exam. This result can be:
    a) Success, the candidate is authorized to take the oral exam (section 2.2),
    b) Failure, the candidate must repeat the written exam as soon as possible,
    c) After a second failure, the candidate is no longer authorized to continue and her/his candidacy ends. The modalities to end the candidacy need to be discussed with the supervisor.
- Although the grade is not communicated, the coordinator (CPES) may communicate certain points about the evaluation to the candidate and to the research supervisors.

To assist in the exam preparation, the graduate program committee recommends the following reference books (the English version is identified by an asterisk *):

1. Mechanics and dynamics (1 question)
   J.R. Taylor, *Mécanique Classique*, (de Boeck, 2005)
   J.R. Taylor, *Classical Mechanics*, (University Science Books, 2005 edition) *
2. Electricity and magnetism (1 question)
   J. P. Pérez *et al*., *Électromagnétisme – Fondements et applications*, 4e édition (Masson)
   A. Zangwill, *Modern Electrodynamics* (Cambridge Univ. Press) * or
   D. J. Griffiths, *Introduction to electrodynamics*, 4th edition (Prentice Hall) *
3. Statistical physics (1 question)
   C. Ngo et H. Ngo, *Physique statistique*, 3e édition (Dunod, 2008)
   Silvio R. A. Salinas, *Introduction to Statistical Physics*, (Springer-Verlag, 2001) *
4. Quantum mechanics (1 question)
   C. Cohen-Tannoudji, B. Liu, F. Laloé, Mécanique quantique, 2e édition (EDP Sciences, 2018)
   D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd edition (Prentice Hall) *
5. Solid-state physics (2 questions)
   C. Kittel, *Physique de l'état solide*, 8e édition, (Dunod, 2007)
   C. Kittel, *Introduction to Solid State Physics*, 8th edition (Wiley) * or
   N. W. Ashcroft et N. D. Mermin, *Solid State Physics* (Brooks Cole, 1976) *
6. Optics (2 questions)
   PHS2223: Course notes
   E. Hecht, *Optics*, 4th edition (Addison Wesley) *

- **The following tables detail the important concepts of the questions in the written test**

Mechanics and dynamics

Bachelor course	Mécanique supérieure (PHS2107)
Typical questions	Understanding, formalism and mathematical calculation

Study guide

Themes	**Important notions**	**Example**
Newtonian mechanics		Taylor: chap. 1
Energy		Taylor: chap. 4

Calculus of variations		Taylor: chap. 6
Lagrangian	Euler-Lagrange's equation	Taylor: chap. 7.1-7.8
Central force movement	Orbital trajectories calculation	Taylor: chap. 8
Rotation of rigid bodies		Taylor: chap. 10.1-10.6
Coupled oscillators	Harmonic system interaction	Taylor: chap. 11
Hamiltonian	Hamilton's equation	Taylor: chap. 13.1-13.6

Electricity and magnetism

Bachelor course	Electromagnétisme (PHS1102) and Fondements et applications de l'électromagnétisme (PHS2112).
Typical Questions	Application of Maxwell's equations to solve problems involving electric charges and currents and electromagnetic fields. Understanding, formalism, and mathematical calculation.

Study guide

Themes	Important notions	Example
Electrostatics	▸ Coulomb and Gauss laws ▸ Electrical potential and energy ▸ Laplace and Poisson equations	Pérez: chap. 1-3; 8 Griffiths: chap. 2, 3 Zangwill: chap. 3, 7, 8
Electric dipole, polarization and dielectric media	▸ Electric dipole and dipolar field ▸ Force and torque on dipoles ▸ Polarization ▸ Permittivity and susceptibility ▸ Capacitor and capacity.	Pérez: chap. 5, 21 Griffiths: chap. 4 Zangwill: chap. 4, 5, 6
Electric conduction and conductors	▸ Continuity equation ▸ Resistivity and conductivity ▸ Power density and power	Pérez: chap. 6, 9 Griffiths: chap. 7.1 Zangwill: chap. 9
Magnetostatics	▸ Biot-Savart law ▸ Ampère Theorem ▸ No divergence on magnetic induction	Pérez: chap. 11 Griffiths: chap. 5 Zangwill: chap. 10
Magnetic medium	▸ Magnetic dipole and dipolar field ▸ Force and torque on dipole ▸ Magnetization, permeability and susceptibility ▸ Magnetic materials ▸ Density of magnetic energy ▸ Hysteresis cycle	Pérez: chap. 22, 26 Griffiths: chap. 6 Zangwill: chap. 11, 12, 13
Electrodynamics	▸ Lorentz force ▸ Electromagnetic induction ▸ Faraday's law ▸ Net and mutual inductance ▸ Displacement currents ▸ Foucault's currents ▸ Generalized Ampere law ▸ Energy density of electromagnetic field	Pérez: chap. 13-16 Griffiths: chap. 7 Zangwill: chap. 14, 15
Electromagnetics in vacuum	▸ Wave equation ▸ Plane waves and spherical waves, polarization ▸ Energy and Poynting vector ▸ Impedance	Pérez: chap. 19-23 Griffiths: chap. 8.1, 9.1, 9.2 Zangwill: chap. 16

Statistical physics

Bachelor course	Physique statistique (PHS2111)
Typical questions	Understanding, formalism, and mathematical calculation

Study guide

Themes	Important notions	References
Review of classical thermodynamics	▸ Laws of thermodynamics ▸ Thermodynamics functions (potential) ▸ Equilibrium conditions	Ngo: chap. 1 Salinas: chap. 1
Postulates of statistical physics	▸ Fundamental postulate ▸ Ergodic hypothesis ▸ Statistical entropy ▸ Average and variances	Ngo: chap. 3 Salinas: chap. 2
Microcanonical ensemble	▸ Entropy ▸ Classical perfect gas ▸ Paradox of Gibbs	Ngo: chap. 5 Salinas: chap. 4
Canonical ensemble	▸ Partition function ▸ Paramagnetism ▸ Solid of Einstein ▸ Free particle in a box	Ngo: chap. 6 Salinas: chap. 5
Classical perfect gas	▸ Maxwell's distribution ▸ Energy equipartition ▸ Rotation and vibration ▸ Diatomic gas	Ngo: chap. 7 Salinas: chap. 6
Grand-canonical ensemble and quantum statistics	▸ Grand canonical ensemble ▸ Bosons and Bose-Einstein distribution ▸ Fermions and Fermi-Dirac distribution	Ngo: chap. 8, 9 Salinas: chap. 7, 9

Quantum mechanics

Bachelor course	Mécanique quantique I (PHS2108)
Typical questions	Understanding, mathematical formalism, solving and interpretation of simple problems

Study guide

Themes	Important notions	References
Mathematical formalism	▸ Operators and observable ▸ Measurement results ▸ Uncertainty principle ▸ Entanglement ▸ Density matrix (pure and mixed states)	Griffiths: chap. 3 Cohen-Tannoudji: chap. 2-3
Schrödinger equation	▸ Interpretation of wave function in real space and wavenumbers space ▸ Infinite and finite well ▸ Harmonic oscillator ▸ Free particle	Griffiths: chaps. 1-2 Cohen-Tannoudji: chap. 1, 3, 5
Schrödinger equation in 3D	▸ Problems in cylindrical and spherical coordinates ▸ Angular momentum ▸ Spin ▸ Hydrogen atom	Griffith: chap. 4 Cohen-Tannoudji: chap. 6, 7, 10
Identical particles	▸ Neutral atoms ▸ Multielectron atoms	Griffiths: chap. 5 Cohen-Tannoudji: chap. 14
Time-independent perturbation theory and Variational principle	▸ non-degenerate ▸ degenerate	Griffith: chap. 6, 7 Cohen-Tannoudji: chap. 11

Optics/Photonics (2 questions)

Bachelor course	Optique moderne (PHS2222), plus notions related to polarization

Typical questions	Understanding, calculations, graphics (rays tracing, schemes of interference or diffraction patterns).

Study guide

Themes	Important notions	References
Propagation of light in dielectrics and Geometrical optics	▸ Refraction index, reflection and refraction ▸ Huygens principle ▸ Fermat principle ▸ Total internal reflection ▸ Conjugated formulas ▸ Magnifications ▸ Ray tracing for lenses, mirrors and associations in simple systems and instruments (eyepieces, glasses, microscope)	Hecht: chap. 4, except sections 4.8, 4.9 and 4.11 Hecht: chap. 5-6
Wave optics	▸ Interference ▸ Interferometry and their applications ▸ Fraunhofer diffraction ▸ Fourier optics ▸ Spatial and temporal coherence	Hecht chap. 7, 9, 10 except 10.3 and 10.4, and 11
Polarization	▸ Polarizer ▸ Dichroism ▸ Birefringence ▸ Fresnel coefficients ▸ Retardation plate ▸ Optical activity	Hecht: pertinent sections of chap. 8

Solid-state physics (2 questions)

Bachelor course	Physique du solide I (PHS3301) and Physique du solide II (PHS3302).
Typical questions	Understanding, mathematical formalism, solving and interpretation of simple problems

Study guide

Themes	Important notions	References
Structure of solids	▸ Crystal structure of solids ▸ Elementary cell: Wigner-Seitz ▸ Reciprocal space	Kittel: chap. 1-2
Phonons	▸ Vibrations in network ▸ Density of states ▸ Thermal properties of solids, specific heat and thermal conductivity	Kittel: chap. 4-5
Electrons in solids	▸ Drude model ▸ Free electron model for metals ▸ Bloch's theorem, Born-Von Karman boundary conditions ▸ Reciprocal space: Brillouin zone ▸ Energy bands ▸ Nearly free electron model and tight-binding method ▸ Density of states, Fermi surface, Fermi-Dirac distribution ▸ Semi-classical model of charge carrier dynamics	Kittel: chap. 6-7
Semi-conductors	▸ Notion of hole, doping, charge carrier statistics, currents of diffusion and drift, recombination of carriers ▸ Continuity equations ▸ Transport in semi-conductors ▸ Hall effect ▸ Thermoelectric effects ▸ Elementary notions of p-n junction	Kittel: chap. 8

Magnetism	▸ Magnetic moments of ions and isolated atoms ▸ Hund rules ▸ Diamagnetism and Langevin formulas ▸ Paramagnetism of isolated ions ensemble ▸ Paramagnetism of Pauli	Kittel: chap. 11-12
Dielectrics	▸ Local field ▸ Lorentz model ▸ Clausius and Mossotti relation ▸ Mechanisms of polarization ▸ Piezoelectric and ferroelectric effects	Kittel: chap. 16

2.2 Oral exam in Engineering Physics

- The research director forms an evaluation panel composed of at least three (3) members: the president, the research supervisor and a third person. The president is chosen from among the members of the department's Graduate Studies Committee. The third person is an external member chosen for the relevance of her/his scientific expertise. The latter, in addition to not being part of the Engineering Physics Department, must not be involved in the student's work.
- The student will receive a written notification indicating the date, time and place of the exam, as well as the composition of the jury and a list of three subjects, decided by the research director, on which she/he could be questioned.
- The candidate must prepare a written document containing no more than 20 pages (without the bibliography) describing the proposed research project. This document is not limited to a review of the literature, it is a real research proposal. The following elements are suggested for inclusion in this research proposal:
    a. title of the project,
    b. summary (1/2 page maximum),
    c. introduction and description of the general context,
    d. description of the present problem,
    e. general presentation of the project and its objectives,
    f. detailed description of the proposed approach and methodology, and if needed, a description of the preliminary results,
    g. description of the originality of the project and its benefits,
    h. timeline,
    i. conclusion,
    j. bibliography (there is no limit on the number of pages).
- The candidate must give the printed document to the members of the jury at least **two (2) weeks before the date of the presentation**. If this deadline is not respected, a member can ask to postpone the date of the exam.
- The student will be judged on the scientific quality of her/his research proposal and her/his ability to carry it out.
- The oral test takes place behind closed doors as follows:
    a. The candidate makes a presentation of a maximum of 40 minutes. It should include all the important elements of the research proposal.
    b. Following the presentation, the members of the jury question the candidate on her/his research project and the three subjects mentioned above. If it is deemed necessary, they may question the student on any subject of engineering physics related, directly or indirectly, to realization of the research project. In addition, they may return to the weaknesses identified during the written exam.
    c. Jury deliberation.
- After deliberation, the jury determines if
    a. the general exam is successful,

b. the general exam is adjourned (maximum of three (3) months) when the evaluation criteria are not completely met. Following recommendations of the jury, the candidate submits a revised written document and makes a new oral presentation,
c. the candidate fails the general exam. This failure ends her/his candidacy.

- The jury communicates its decision to the candidate immediately after the deliberation period.
- It should be noted that only one repeat is granted. Thus, if the candidate has benefited from a repeat of the written exam, she/he cannot benefit from a resumption of the oral exam.
- Following the successful completion of the general comprehensive examination, the student then becomes a candidate for a thesis project.

3. Preparation of the dissertation and the thesis

3.1 Style templates and electronic submission

The dissertation and the thesis must follow the presentation rules established by Polytechnique Montréal. To help you focus on the content rather than the form, style templates have been prepared for Word and LaTeX software (https://guides.biblio.polymtl.ca/these/guides). Note that the use of these style templates is mandatory.

The final submission of dissertations and theses must be done electronically in PDF format. The procedures to follow are available on the website of Polytechnique; they will guide you during this last step before graduation.

4. The defence of the thesis and the presentation of the dissertation

4.1 Procedure leading to the PhD thesis defence

One of the most important events in university life is the defence of a thesis. Since it leads to the highest degree, universities pay particular attention to the procedure with which the award criteria are applied, in order to justify the recognition and credibility the doctoral degree affords.

The procedure leading to the defence is mainly determined by two important periods. The first is the time allocated to reviewers to prepare their evaluation reports. It is estimated that a minimum period of four (4) weeks is necessary to prepare a rigorous evaluation while offering some flexibility.

The second important period is the public announcement of the defence. Thus, following a positive recommendation from the jury, the defence will be announced for a minimum period of two (2) weeks. This allows anyone who has doubts about the validity or quality of the work to object. Although this is a very rare event, this rule adds legitimacy to the award of the diploma.

Thus, the submission of the thesis must be made at least **six (6) weeks before the date of the defence**. If for any reason one of the deadlines were not respected, it would then be necessary to delay the defence.

The following table summarizes the procedures to follow. The student and the research director must ensure that they are respected in order to avoid postponing the scheduled date of the defence.

Themes	Participant	Action
	Research supervisor	The following forms are completed: 1) Nomination of the jury (ES-GR-12F); 2) Articles-based dissertation or thesis (ES-GR-07F); 3) Nomination of the representative of the director of graduate studies (DGS), (ES-GR-10F); 4) Choose the date and time for the defence and communicate with the student records officer.

After approval of the jury composition and at least **6 weeks** before the date of the defence	Candidate	A PDF copy of the thesis is sent to the student records officer.
At least **6 weeks** before the date of the defence	Student records officer	1) The thesis is verified with the software TURNITIN. If more than 15% of similarity is found, a copy of the report is transmitted to the CPES; 2) A PDF copy of the thesis is sent to each member of the jury, including the representative of the DGS; 3) A copy of the examiner report (ES-GR-05F) is sent to every jury member, and the associated deadlines to respect; 4) A note is sent to the jury members that if they prefer to have a hard copy of the thesis, they need to contact the student to obtain one; an email address of the student is provided.
Around **3 weeks** before the date of the defence	Student records officer	Reminds the reviewers of the submission date and informs the research director if evaluation reports are missing. **NOTE: It is the responsibility of the supervisor to ensure that all reports are delivered on time.**
At least **2 weeks** before the date of the defence	President of the jury	Authorizes, following positive recommendations from the reviewers, the status of the defence by signing and dating the form "Evaluation report for presentation or defence."
At least **2 weeks** before the date of the defence	Student records officer	Sends the evaluation reports of the reviewers to the president of the jury and to the representative of the DGS, and announces the thesis defence.
Day of the defence	President of the jury	Chairs the thesis defence following the usual procedure.

4.2 Procedure leading to presentation of MSc dissertation

The procedure leading to the presentation of the dissertation is strongly inspired by the procedure presented above for the PhD defence. However, this is shorter by a reduction of the evaluation period to three weeks and the public announcement period to one week.

Hence, the submission of the dissertation must be made at least **four (4) weeks before the date of the presentation**. If for any reason one of the deadlines were not respected, it would then be necessary to delay the presentation.

The following table summarizes the procedures to follow. The student and the research supervisor need to ensure that they are respected in order to avoid delaying the presentation.

Themes	Participant	Action
	Research supervisor	The following forms are completed: 1) Nomination of the jury (ES-GR-12F); 2) Articles-based dissertation or thesis (ES-GR-07F); 3) Choose the date and time for the defence and communicate to the student records officer.
After the composition of the jury has been approved and at least **4 weeks** before the date of the presentation	Candidate	A PDF copy of the MSc dissertation is sent to the student records officer.
At least **4 weeks** before the date of the presentation	Student records officer	1) The dissertation is verified with the software TURNITIN. If more than 15% of similarity is found, a copy of the report is transmitted to the CPES; 2) A PDF copy of the dissertation is sent to each member of the jury, including the representative of the DGS; 3) A copy of the examiner report (ES-GR-05F) is sent to every jury member, and the associated deadlines to respect; 4) A note is sent to the jury members that if they prefer to have a hard copy of the dissertation, they need to contact the

		student to obtain one; an email address of the student is provided.
At least **2 weeks** before the date of the presentation	Student records officer	Reminds the reviewers of the submission date and informs the research director if evaluation reports are missing. **NOTE: It is the responsibility of the supervisor to ensure that all reports are delivered on time.**
At least **1 week** before the date of the presentation	President of the jury	Authorizes, following positive recommendations from the reviewers, the status of the defence by signing and dating the form "Evaluation report for presentation or defence."
At least **1 week** before the date of the presentation	Student records officer	Sends the evaluation reports of the reviewers to the president of the jury and to the representative of the DGS; and announces the defence of the dissertation.
Day of the presentation	President of the jury	Chairs the dissertation defence following the usual procedure.

5. Plagiarism

"All rules and sanctions of Polytechnique (https://etudiant.polymtl.ca/plagiat/reglement-et-sanctions) apply to cases of master's theses and doctoral dissertations. If there is suspicion of fraud or plagiarism, a committee examines whether there is an infringement or not and decides on the sanction to be applied. **An infringement could lead to the termination of the student's candidacy**.

6. Interrupting your graduate program

If, for any reason, you need to interrupt or conclude your studies before obtaining a degree, you must inform several individuals at Polytechnique. Firstly, you must communicate your intention to your research supervisor. Also, please inform the student records agent. She will remind you of the important steps to follow to conclude your candidacy.

Finally, **it is imperative that you inform the registrar's office**. Indeed, for logistical reasons, enrollment in the Graduate School is automatically renewed each semester, even if you are not enrolled in any credits. If the registrar's office is not notified of your departure, tuition fees will accumulate in your record, and Polytechnique may resort to a collection agency to recover unpaid fees."