SFU Office of Graduate Studies and Postdoctoral Fellows

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**MEMORANDUM**

| | | | |
|---|---|---|---|
| ATTENTION | Senate | DATE | 16 September 2014 |
| FROM | Wade Parkhouse, Dean of Graduate Studies | No. | GS2014.31 |
| RE: | Faculty of Science | | |

For information:

Acting under delegated authority at its meeting of September 8, 2014, SGSC approved the following new course effective Summer 2015:

**Faculty of Science**

Physics

New course: PHYS 822-3 Advanced Electromagnetism II

W Parkhouse

SFU

MEMO

Faculty of Science

ATTENTION Wade Parkhouse, Dean, Graduate Studies

FROM Peter Ruben, Associate Dean, Research and Graduate Studies, Faculty of Science

RE Physics - New Graduate Course

DATE July 25, 2014

TIME 3:40 PM

The introduction of a new course, PHYS 822, Electromagnetism II, is requested by the Department of Physics. This new course has been approved by the Faculty of Science, has elicited no overlap concerns from other Faculties, and is forwarded for approval by the Senate Graduate Studies Committee. Please include this item on the next SGSC agenda.

P. Ruben

SIMON FRASER UNIVERSITY
DEAN OF GRADUATE STUDIES

# New Graduate Course Proposal Form

## PROPOSED COURSE

Program (eg. ECON) PHYS | Number (eg. 810) 822 | Units (eg. 4) 3

Course Title (max 80 characters)
Advanced Electromagnetism II

Short Title (appears on transcripts, max 25 characters)
Electromagnetism II

Course Description for SFU Calendar ☒ see attached document ☒ Learning outcomes identified

Advanced topics in electromagnetic waves: propagation and polarization in free space and in macroscopic media, including dispersive and anisotropic media; conducting and dielectric waveguides and resonators; radiation, scattering, and diffraction.

Available Course Components: ☒ Lecture ☐ Seminar ☐ Laboratory ☐ Practicum ☐ Online ☐ ____________

Grading Basis ☒ Graded ☐ Satisfactory/Unsatisfactory ☐ In Progress/Complete

Prerequisites (if any) ☐ see attached document

PHYS 421, or equivalent.

☐ This proposed course is combined with an undergrad course: Course number and units: ____________

Additional course requirements for graduate students ☐ See attached document (if this space is insufficient)

Campus at which course will be offered (check all that apply) ☒ Burnaby ☐ Vancouver ☐ Surrey ☐ GNW ☐ ____________

| Estimated enrolment | Date of initial offering | Course delivery (eg. 3 hrs/week for 13 weeks) |
|---|---|---|
| 10-15, every ~2 years | Spring 2015 | 3 hrs/week for 13 weeks |

Justification ☒ See attached document

## RESOURCES

If additional resources are required to offer this course, the department proposing the course should be prepared to provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course ☐ information about their competency to teach the course is appended
Broun, Dodge, Hayden, and many others

Number of additional faculty members required in order to offer this course
None

Additional space required in order to offer this course ☐ see attached document
None

Additional specialized equipment required in order to offer this course ☐ see attached document
None

Additional Library resources required (append details) ☐ Annually $____________ ☐ One-time $____________
None

## PROPOSED COURSE *from first page*

| Program (eg. ECON) PHYS | Number (eg. 810) 822 | Units (eg. 4) 3 |
|---|---|---|
| Course title (max 80 characters)<br>Advanced Electromagnetism II | | |

## APPROVAL SIGNATURES

When a department proposes a new course it must first be sent to the chairs of each faculty graduate program committee where there might be an overlap in course content. The chairs will indicate that overlap concerns have been dealt with by signing the appropriate space or via a separate memo or e-mail (attached to this form).

The new course proposal must also be sent to the Library for a report on library resources.

Once overlap concerns have been dealt with, signatures indicate approval by the department, home faculty and Senate Graduate Studies Committee.

**Other Faculties**
The signature(s) below indicate that the Dean(s) or designate of other Faculties affected by the proposed new course support(s) the approval of the new course.

| Name of Faculty | Signature of Dean or Designate | Date |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

**Departmental Approval** (non-departmentalized faculties need not sign)

| Department Graduate Program Committee<br>Eldon Emberly | Signature | Date Mar 26, 2014 |
|---|---|---|
| Department Chair<br>Simon Watkins | Signature | Date Mar 26, 2014 |

**Faculty Approval**
Faculty approval indicates that all the necessary course content and overlap concerns have been resolved, and that the Faculty/Department commits to providing the required Library funds and any other necessary resources.

| Faculty ~~Graduate~~ Program Committee<br>PETER RUBEN | Signature | Date 25 Jun 2014 |
|---|---|---|

**Senate Graduate Studies Committee Approval**
SGSC approval indicates that the Library report has been seen, and all resource issues dealt with. Once approved, new course proposals are sent to Senate for information.

| Senate Graduate Studies Committee<br>WADE PARKHOUSE | Signature | Date Sept 18/14 |
|---|---|---|

## CONTACT

Upon approval of the course, the Dean of Graduate Studies office will consult with the department or school regarding other course attributes that may be required to enable the proper entry of the new course in the student record system.

| Department / School / Program<br>PHYS | Contact name<br>Stephen Flach | Contact email<br>physgrad@sfu.ca |
|---|---|---|

# PHYS 822-3 - Advanced Electromagnetic Waves - Spring 201x

Faculty, Any <faculty(at)sfu(dot)ca>
Phone 778.782.xxxx
Fax 778.782.3592

Electromagnetic waves in free space and in macroscopic media, including dispersive and anisotropic media; conducting and dielectric waveguides and resonators; radiation, scattering, and diffraction. Prerequisite: PHYS 421, or equivalent.

Electromagnetic waves in free space and in macroscopic media, including dispersive and anisotropic media; conducting and dielectric waveguides and resonators; radiation, scattering, and diffraction.

- Wave equation from Maxwell's equations; plane waves; polarization; scalar wave approximation; Helmholtz equation.
- Beams; wave angular momentum; spherical waves; Hertz vectors; forces on particles.
- Waves in nondispersive matter; eikonal equation; reflection and refraction; radiation pressure; layered media; conducting media.
- Waves in anisotropic media; dielectric tensor; characteristic waves; wave propagation in uniaxial crystals.
- Frequency dispersion; energy in dispersive matter; transverse and longitudinal waves; classical models of frequency dipsersion.
- Wave packet propagation in dispersive media; Kramers-Kronig relations; spatial dispersion.
- Transmission lines and conducting waveguides.
- Dielectric waveguides; conducting cavities; dielectric resonators.
- Inhomogeneous wave equations; retardation; electric dipole radiation.
- Antennas; multipole radiation; radiation in matter.
- Scattering cross section; Thomson scattering; Rayleigh scattering; exactly solvable scattering problems; approximation methods in scattering; diffraction theory.
- Liénard-Wiechert potentials and fields; radiation from accelerated charge.
- Synchrotron radiation; radiation reaction; Cherenkov radiation.

AQ5008
MWF
10:30AM - 11:20AM

| | | |
|---|---|---|
| A. Zangwill | ***Modern Electromagnetism*** | 1st Edition |
| J.D. Jackson | ***Classical Electrodynamics*** | 2nd or 3rd Edition |
| L.D. Landau & E.M. Lifshitz | ***The Classical Theory of Fields*** | 4th Edition |
| L.D. Landau, E.M. Lifshitz, and L.P. Pitaevskii | ***Electrodynamics of Continuous Media*** | 2nd Edition |

Assignments 50%
Mid-term 15%
Final exam 35%

Students who cannot write their exam during the course's scheduled exam time must request accommodation from their instructor in writing, clearly stating the reason for this request, before the end of the first week of classes.

Proposed calendar description for PHYS 822:
Advanced topics in classical electromagnetic theory: graduate-level review of Maxwell's equations in free space and in macroscopic media, with applications in contemporary research; relativistic unification of electromagnetism; Lagrangian and Hamiltonian methods in electromagnetism.

Summary of graduate-level goals appropriate for the "graduate-level review of Maxwell's equations," taken from the first fifteen chapters of Zangwill, *Modern Electrodynamics*. Familiarity with electromagnetism at the level of Griffiths is assumed.

1. **Mathematical Preliminaries**
   a) Facility with the Einstein summation convention with the Kronecker and Levi-Cività symbols to simplify complex vector expressions.
   b) Ability to derive and interpret vector identities, in coordinate-free vector notation and for curvilinear components.
   c) Facility with vector derivatives, especially functions of $\boldsymbol{r}$, $|\boldsymbol{r}|$, and $\boldsymbol{r}-\boldsymbol{r}'$, as well as the convective derivative, and Taylor's theorem for multivariable functions.
   d) Familiarity with integral calculus on vector fields, beyond the divergence theorem and Stokes' theorem: the use of the Jacobian in coordinate transformations, Green's identities, and the time derivative of a flux integral.
   e) Facility with generalized functions in one and higher dimensions, including the principle value integral, products of delta functions, and delta functions over functional arguments.
   f) Facility with Fourier analysis, including Parseval's theorem, the convolution theorem, and time-averaged products of complex fields.
   g) Familiarity with the transformation properties of tensors and pseudotensors.
   h) Familiarity with the proof and application of the Helmholtz theorem.
   i) Familiarity with the use of Lagrange multipliers for constrained minimization.
2. **The Maxwell Equations**
   a) Appreciation of the distinction between microscopic and macroscopic fields, and the role of macroscopic averaging in connecting them.
   b) Appreciation of the relationship between classical and quantum electrodynamics.
3. **Electrostatics**
   a) Ability to calculate the electrostatic potential and field for charge configurations that require graduate-level mathematical sophistication.
   b) Familiarity with Green's reciprocity relation.
   c) Familiarity with the electric stress tensor in vacuum.
4. **Electric Multipoles**
   a) Familiarity with the electric multipole expansion in Cartesian and spherical forms, with and without azimuthal symmetry (ie, with Legendre polynomials and spherical harmonics), and with an appreciation for the singularities that appear at the origin.
   b) Ability to determine dipole and quadrupole moments of an arbitrary charge distribution, and to calculate forces and torques on point dipoles and quadrupoles in an inhomogeneous field.
5. **Conducting Matter**
   a) Familiarity with the capacitance matrix and inverse capacitance matrix for multiple conductors, and an awareness of their use in determining the energy of a system of conductors.
   b) Ability to determine the energy of a system of conductors held at constant charge or potential.
   c) Appreciation of the importance of using the correct thermodynamic potential to determine the forces on conductors.

d) Ability to calculate the forces among a system of conductors, while holding their charges or potentials constant.
e) Qualitative appreciation of the differences between real and ideal conductors.

6. **Dielectric Matter**
a) Appreciation for the ambiguities associated with the Lorentz model of polarization, and an awareness of how they are removed in the modern theory of polarization.
b) Ability to derive boundary matching conditions on ***E*** and ***D*** from Maxwell's equations, in terms of vector expressions that involve the boundary surface normal; ability to apply these to boundary value problems.
c) Appreciation for the role of local field effects in determining induced polarization, and familiarity with mean-field approximations like the Clausius-Mossotti formula.
d) Appreciation of the importance of using the correct thermodynamic potential to determine the electric field energy of a dielectric.
e) Ability to calculate the electrostatic force on an isolated dielectric body, the force density on a dielectric medium, and the electric stress tensor for a simple dielectric.

7. **Laplace's Equation**
a) Familiarity with the general framework of potential theory, and the ability to calculate solutions to the Laplace equation for Cartesian, cylindrical, and spherical geometries, including spherical geometries that lack azimuthal symmetry.
b) Ability to use the theory of analytic functions, including conformal mapping, to solve the Laplace equation in two dimensions.

8. **Poisson's Equation**
a) Ability to use the method of images to solve graduate-level problems in electrostatics, such as a line charge outside a conducting or dielectric cylinder.
b) Ability to use the Green function method for solving Poisson's equation in Cartesian, cylindrical, and spherical geometries.

9. **Steady Current**
a) Ability to apply potential theory to determine ***E(r)*** and ***j(r)*** for steady current flow in homogeneous ohmic matter.
b) Ability to calculate the current density that will minimize Joule heating in an inhomogeneous conductor.
c) Familiarity with Fick's law and the Einstein relation for diffusion currents.

10. **Magnetostatics**
a) Ability to calculate the magnetic field for steady current configurations that require graduate-level mathematical sophistication.
b) Familiarity with the magnetic scalar potential and the ability to apply it to solve appropriate magnetostatic problems.

11. **Magnetic Multipoles**
a) Familiarity with the magnetic multipole expansion in Cartesian and spherical forms, with and without azimuthal symmetry, for volumes exterior and interior to the current distribution, and with an appreciation for the singularities that appear at the origin.
b) Awareness of the spin and orbital magnetic moments in quantum systems.

12. **Magnetic Force and Energy**
a) Ability to calculate the force between two arbitrary current densities; the force, energy, and torque of a magnetic dipole in a magnetic field; and the dipole-dipole interaction energy.
b) Familiarity with Larmor precession.
c) Familiarity with the magnetic stress tensor in vacuum.
d) Ability to determine the magnetic energy of a system for constant current or flux.
e) Appreciation of the importance of using the correct thermodynamic potential to determine

magnetic forces.

f) Ability to calculate magnetic forces in terms of inductance.

13. **Magnetic Matter**
    a) Awareness of spin, orbital, and total magnetization, and the role of macroscopic averaging in determining the magnetization.
    b) Ability to use potential theory and the method of images to determine the magnetic field of magnetized matter, and awareness of the limiting cases for the permeability $\mu$.
    c) Familiarity with the demagnetization field.
    d) Ability to derive boundary matching conditions on $\boldsymbol{B}$ and $\boldsymbol{H}$ from Maxwell's equations, in terms of vector expressions that involve the boundary surface normal, and to apply these to boundary value problems.
    e) Appreciation of the importance of using the correct thermodynamic potential to determine the magnetic field energy of a magnetized medium.
    f) Ability to calculate the magnetostatic force on an isolated magnetic body, the force density on a magnet, and the magnetic stress tensor for a simple magnet.
14. **Dynamic and Quasistatic Fields**
    a) Familiarity with the quasistatic approximations to Maxwell's equations, including their application to poor conductors and good conductors.
    b) Familiarity with the skin effect, and awareness of how it influences the current density in a wire at high frequencies.
    c) Ability to calculate the complex impedance of an AC circuit network.
15. **General Electromagnetic Fields**
    a) Familiarity with the transformation properties of electromagnetic quantities under discrete symmetry transformations.
    b) Awareness of the dual transformation between electric and magnetic fields.
    c) Familiarity with the continuous symmetries of electromagnetism, including Lorentz symmetry and gauge invariance, and an awareness of their relationship to conserved quantities.
    d) Familiarity with the Coulomb and Lorentz gauges, and their role in simplifying expressions involving the electromagnetic potentials.
    e) Familiarity with the electromagnetic expressions for conservation of energy, momentum, and angular momentum, both in vacuum and in matter.
    f) Awareness of the Abraham-Minkowski controversy over the definition of the electromagnetic momentum density in matter.
    g) Ability to calculate, given a suitable electromagnetic field, the energy density, momentum current density, angular momentum current density, the center of energy, and the electromagnetic stress tensor.