**Official Undergraduate Course Outline Form**

*Note: The University reserves the right to amend course outlines as needed without notice.*

<table>
<thead>
<tr>
<th>Course Code and Number: PHYS 452</th>
<th>Number of Credits: 3 [Course credit policy (105)]</th>
</tr>
</thead>
</table>

**Course Full Title:** Introduction to General Relativity  
**Course Short Title (if title exceeds 30 characters):**  

**Faculty:** Faculty of Science  
**Department (or program if no department):** Physics  

**Calendar Description:**  
Einstein’s theory of general relativity; a description of gravity as a consequence of the curvature of spacetime; introduction to differential geometry and geodesics; Schwarzschild metric, gravitational waves, and FLRW cosmology.

**Prerequisites (or NONE):** PHYS 352  
**Corequisites (if applicable, or NONE):** NONE  
**Pre/corequisites (if applicable, or NONE):**  

**Equivalent Courses (cannot be taken for additional credit)**  
**Former course code/number:** N/A  
**Cross-listed with:** N/A  
**Equivalent course(s):** N/A  
*Note: Equivalent course(s) should be included in the calendar description by way of a note that students with credit for the equivalent course(s) cannot take this course for further credit.*

**Total Hours:** 75  
**Typical structure of instructional hours:**  
| Lecture hours | 75 |
| Seminars/tutorials/workshops |  
| Laboratory hours |  
| Field experience hours |  
| Experiential (practicum, internship, etc.) |  
| Online learning activities |  
| Other contact hours: |  
| **Total** | 75 |

**Transfer Credit**  
**Transfer credit already exists:** ☑ Yes ☐ No  
**Transfer credit requested (OReg to submit to BCCAT):** ☑ Yes ☐ No (if yes, fill in transfer credit form)  
**Resubmit revised outline for articulation:** ☑ Yes ☐ No  
*To find out how this course transfers, see [bctransferguide.ca](http://bctransferguide.ca).*

**Special Topics**  
**Will the course be offered with different topics?** ☑ Yes ☐ No  
**If yes, different lettered courses may be taken for credit:** ☑ No ☑ Yes, repeat(s) ☑ Yes, no limit  
*Note: The specific topic will be recorded when offered.*

**Maximum enrolment (for information only):** 24  
**Expected frequency of course offerings (every semester, annually, every other year, etc.):** Once every two years

**Department / Program Head or Director:** Derek Harnett  
**Date approved:** August 27, 2014  
**Campus-Wide Consultation (CWC):**  
**Date of posting:** n/a  
**Faculty Council approval**  
**Date approved:** October 3, 2014  
**Dean/Associate VP:** Lucy Lee  
**Date approved:** October 3, 2014  
**Undergraduate Education Committee (UEC) approval**  
**Date of meeting:** October 24, 2014
Learning Outcomes
Upon successful completion of this course, students will be able to:
- compute geometric quantities such as length, area, volume, and proper time given a line element in an arbitrary Riemannian space or Lorentzian spacetime
- transform line elements between coordinate systems
- define timelike and null geodesics
- compute Christoffel symbols from line elements
- sketch local lightcones in an effort to identify event horizons
- determine two-dimensional embeddings in flat three-dimensional space corresponding to spherically symmetric spacetimes
- solve relativistic kinematics problems in the exterior Schwarzschild geometry
- explain the phenomenon of gravitational lensing
- explain the key principles underlying direct detection of gravitational radiation
- relate the rate of the universe's expansion to the gravitational red shift and the age of the universe

Prior Learning Assessment and Recognition (PLAR)
☒ Yes ☐ No, PLAR cannot be awarded for this course because

Typical Instructional Methods (guest lecturers, presentations, online instruction, field trips, etc.; may vary at department's discretion)
Lectures, computer simulations, projects

NOTE: The following sections may vary by instructor. Please see course syllabus available from the instructor.

Typical Text(s) and Resource Materials (if more space is required, download Supplemental Texts and Resource Materials form)

<table>
<thead>
<tr>
<th>Author (surname, initials)</th>
<th>Title (article, book, journal, etc.)</th>
<th>Current ed.</th>
<th>Publisher</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Wald, R.M.</td>
<td>General Relativity</td>
<td>☒ Chicago</td>
<td>1984</td>
<td></td>
</tr>
<tr>
<td>5. Carroll, Sean</td>
<td>Spacetime and Geometry: An Introduction to General Relativity</td>
<td>☒ Addison-Wesley</td>
<td>2003</td>
<td></td>
</tr>
</tbody>
</table>

Required Additional Supplies and Materials (software, hardware, tools, specialized clothing, etc.)
Use this section for supplies and materials for all sections of this course.

Typical Evaluation Methods and Weighting

<table>
<thead>
<tr>
<th>Evaluation Method</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final exam</td>
<td>40%</td>
</tr>
<tr>
<td>Assignments</td>
<td>15%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>0%</td>
</tr>
<tr>
<td>Practicum</td>
<td>%</td>
</tr>
<tr>
<td>Quizzes/tests</td>
<td>30%</td>
</tr>
<tr>
<td>Lab work</td>
<td>%</td>
</tr>
<tr>
<td>Field experience</td>
<td>%</td>
</tr>
<tr>
<td>Shop work</td>
<td>%</td>
</tr>
<tr>
<td>Project:</td>
<td>15%</td>
</tr>
<tr>
<td>Other</td>
<td>%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

Details (if necessary):
Grading system: Letter Grades: ☒ Credit/No Credit: ☐ Labs to be scheduled independent of lecture hours: Yes ☐ No ☒

Typical Course Content and Topics
1. Introductory differential geometry
2. Newtonian gravity
3. Special relativity review
4. Gravity as geometry
5. Geodesics
6. The Schwarzschild metric
7. Gravitational waves
8. Cosmology