ASTR378

General Relativity

S2 Day 2019

Dept of Physics and Astronomy

Contents

General Information

Unit convenor and teaching staff
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Credit points
3

Prerequisites
PHYS301

Corequisites

Co-badged status

Unit description
This unit presents Einstein's theory of general relativity. The unit begins with a review of the ideas of geometry, and the presentation of special relativity from a geometric perspective, gravity as geometry, and the equivalence principle. Curved spacetime, metrics, geodesics, and Schwarzschild geometry, are then introduced. Only then is tensor analysis and the full description of spacetime curvature developed and used in the derivation of Einstein's field equations. Applications to classical tests of relativity, the Schwarzschild metric, black holes, and gravitational waves are considered.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

Have an appreciation of the impact of relativity theory on our understanding of the nature of space and time.
Working knowledge of the Lagrangian mechanics, calculus of variations and differential geometric concepts, particularly in their application to relativistic physics and technology.
Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

General Assessment Information

To pass this unit you must:

- submit at least 7 valid home assignments [that contain more than just your name and copy of the question],

- obtain a mark of at least 50% in the unit overall.

Assessment Tasks

Name	Weighting	Hurdle	Due
Assignments: approx weekly	30%	Yes	approx weekly
1 mid-session test, 50 min	15%	No	week 7
Final examination	55%	No	TBA

Assignments: approx weekly

Due: **approx weekly**
Weighting: **30%**
This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)

Assignments are intended primarily for your training as well as for the assessment purposes. They will be issued approximately once a week, covering the studied topics. There will be at least 11 assignments. The best eight assignments [unless agreed otherwise] from the course will be selected to contribute to the assignment grade.

Submission: 1. Students should present their own solutions and should explicitly acknowledge those they have worked with on the assignment. 2. Assignments should be submitted by the due date, unless agreed otherwise beforehand. Extensions can be given only until solutions are published.

Return: The marked assignments will be returned within one-two weeks after the due date.

Hurdle: To pass the unit you have to submit 7 assignments.

Marking: The eight best assignments will be selected to calculate your mark.

On successful completion you will be able to:

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- Working knowledge of the Lagrangian mechanics, calculus of variations and differential geometric concepts, particularly in their application to relativistic physics and technology.
- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

1 mid-session test, 50 min

Due: **week 7**
Weighting: **15%**

Lagrangian mechanics, mathematical techniques and the physical content of special relativity are the foundation for the entire unit. These topics are examined in the in-class exam during week 7. It will allow for an early feedback and adjustments in teaching and learning. The precise date/ time to be set in consultation with the students.

Permitted materials: TBA

On successful completion you will be able to:

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- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
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Final examination

Due: **TBA**
Weighting: **55%**

Three hour final exam during the exam period set by the University. It may cover any of the topics studied in the unit. Allowed materials are to be determined in consultation with the students.

You are expected to present yourself for the final examination at the time and place designated in the University examination timetable (https://iexams.mq.edu.au/timetable). The timetable will be available in draft form approximately eight weeks before the commencement of examinations and in final form approximately four weeks before the commencement of examinations.

If you receive special consideration for the final exam, a supplementary exam will be scheduled after results are released. Please see FSE101 in iLearn for dates. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. Approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination. Second chance exams for hurdle assessments will also be scheduled in this period.

On successful completion you will be able to:

- Have an appreciation of the impact of relativity theory on our understanding of the nature of space and time.
- Working knowledge of the Lagrangian mechanics, calculus of variations and differential geometric concepts, particularly in their application to relativistic physics and technology.
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Delivery and Resources

Classes

All classes will be lectures or tutorials presented on the whiteboard or computer slides.

Class times and locations

- Mon 9:00-11:00
- Tue 15:00-17:00

Updates/changes will appear on https://timetables.mq.edu.au/2019/

Required and Recommended Texts and/or Materials

Required Text

James Hartle: Gravity: An Introduction to Einstein's General Relativity.

Technology used and required

Unit web page

The web page for this unit can be found at http://ilearn.mq.edu.au

Please check this web page regularly for announcements and material available for downloading. Some learning resources for the unit will be provided in hardcopy rather on-line.

Teaching and Learning Strategy

This unit is taught through lectures and tutorials. We strongly encourage students to attend lectures because they provide a much more interactive and effective learning experience than studying a textbook. Even more so we encourage students to skim the suggested reading before classes and actually read the texts afterwards. Questions during and outside lectures are strongly encouraged in this unit - please do not be afraid to ask, as it is likely that your classmates will also want to know the answer.

You may wish to discuss your assignment problems with other students and the lecturers, but you are required to hand in your own work (see the note on plagiarism below). Assignments are provided as one of the key learning activities for this unit, they are not there just for assessment. It is by applying knowledge learned from lectures and textbooks to solve problems that you are best able to test and develop your skills and understanding of the material.

Unit Schedule

TBA at the first class & posted on iLearn

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy
- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy *(**Note:** The Special Consideration Policy is effective from 4 December 2017 and replaces the Disruption to Studies Policy.)*

Undergraduate students seeking more policy resources can visit the Student Policy Gateway (htt

ps://students.mq.edu.au/support/study/student-policy-gateway). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

If you would like to see all the policies relevant to Learning and Teaching visit Policy Central (https://staff.mq.edu.au/work/strategy-planning-and-governance/university-policies-and-procedures/policy-central).

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/study/getting-started/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Disruption to Studies

The University recognises that students may experience disruptions that adversely affect their academic performance in assessment activities. Support Services are provided by the University to assist students through their studies. Whilst advice and recommendations may be made to a student, it is ultimately the student's responsibility to access these services as appropriate. Further information is to be found at http://students.mq.edu.au/student_admin/exams/disruption_to_studies/

Academic Honesty Policy

The University has developed an academic honesty policy whose key principles requires all students and staff to undertake their academic work honestly. Dishonest student behaviours by will be managed by

1. communicating to students that any piece of academic work can be checked at any time using an appropriate process
2. implementing a common remedial and penalty framework across the University
3. establishing and applying appropriate, consistent procedures for detecting and investigating alleged academic dishonesty
4. providing and communicating the appeal process This policy covers such dishonest academic behaviours as

Plagiarism: Using the work or ideas of another person and presenting this as your own without clear acknowledgement of the source of the work or ideas. This includes, but is not limited to, any of the following acts:

– copying out part(s) of any document or audio-visual material or computer code or website content without indicating their origins

– using or extracting another person's concepts, experimental results, or conclusions

– summarising another person's work

– submitting substantially the same final version of any material as another student in an assignment where there was collaborative preparatory work

– use of others (paid or otherwise) to conceive, research or write material submitted for assessment

– submitting the same or substantially the same piece of work for two different tasks (self-plagiarism).

Deception: includes, but is not limited to, false indication of group contribution, false in- dication of assignment submission, collusion, submission of a work previously submitted, creating a new article out of an existing article by rewriting/reusing it, using the same data to form the same arguments and conclusion, presenting collaborative work as one's own without acknowledging others' contributions, cheating in an examination or using others to write material for examination.

Fabrication: includes, but is not limited to, creating fictitious clinical data, citation(s), or referee reports.

Sabotage: includes, but is not limited to, theft of work, destruction of library materials. Full details of the academic honesty policy can be found on http://www.mq.edu.au/policy/docs/academic_honesty/policy.html

Extensions

Assignments: Extensions may be granted on case-by-case basis with requests made prior to the deadline.

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to improve your marks and take control of your study.

- Workshops
- StudyWise
- Academic Integrity Module for Students
- Ask a Learning Adviser

Student Services and Support

Students with a disability are encouraged to contact the Disability Service who can provide

appropriate help with any issues that arise during their studies.

Student Enquiries

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Graduate Capabilities

Creative and Innovative

Our graduates will also be capable of creative thinking and of creating knowledge. They will be imaginative and open to experience and capable of innovation at work and in the community. We want them to be engaged in applying their critical, creative thinking.

This graduate capability is supported by:

Learning outcomes

- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Assessment task

- Assignments: approx weekly

Capable of Professional and Personal Judgement and Initiative

We want our graduates to have emotional intelligence and sound interpersonal skills and to demonstrate discernment and common sense in their professional and personal judgement. They will exercise initiative as needed. They will be capable of risk assessment, and be able to handle ambiguity and complexity, enabling them to be adaptable in diverse and changing environments.

This graduate capability is supported by:

Learning outcomes

- Working knowledge of the Lagrangian mechanics, calculus of variations and differential

geometric concepts, particularly in their application to relativistic physics and technology.
- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Assessment task

- Final examination

Commitment to Continuous Learning

Our graduates will have enquiring minds and a literate curiosity which will lead them to pursue knowledge for its own sake. They will continue to pursue learning in their careers and as they participate in the world. They will be capable of reflecting on their experiences and relationships with others and the environment, learning from them, and growing - personally, professionally and socially.

This graduate capability is supported by:

Learning outcomes

- Working knowledge of the Lagrangian mechanics, calculus of variations and differential geometric concepts, particularly in their application to relativistic physics and technology.
- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.

Assessment task

- Assignments: approx weekly

Discipline Specific Knowledge and Skills

Our graduates will take with them the intellectual development, depth and breadth of knowledge, scholarly understanding, and specific subject content in their chosen fields to make them competent and confident in their subject or profession. They will be able to demonstrate, where relevant, professional technical competence and meet professional standards. They will be able to articulate the structure of knowledge of their discipline, be able to adapt discipline-specific knowledge to novel situations, and be able to contribute from their discipline to inter-disciplinary solutions to problems.

This graduate capability is supported by:

Learning outcomes

- Have an appreciation of the impact of relativity theory on our understanding of the nature

of space and time.
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- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Assessment tasks

- Assignments: approx weekly
- 1 mid-session test, 50 min
- Final examination

Critical, Analytical and Integrative Thinking

We want our graduates to be capable of reasoning, questioning and analysing, and to integrate and synthesise learning and knowledge from a range of sources and environments; to be able to critique constraints, assumptions and limitations; to be able to think independently and systemically in relation to scholarly activity, in the workplace, and in the world. We want them to have a level of scientific and information technology literacy.

This graduate capability is supported by:

Learning outcomes

- Have an appreciation of the impact of relativity theory on our understanding of the nature of space and time.
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- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Assessment tasks

- Assignments: approx weekly
- 1 mid-session test, 50 min
- Final examination

Problem Solving and Research Capability

Our graduates should be capable of researching; of analysing, and interpreting and assessing data and information in various forms; of drawing connections across fields of knowledge; and they should be able to relate their knowledge to complex situations at work or in the world, in order to diagnose and solve problems. We want them to have the confidence to take the initiative in doing so, within an awareness of their own limitations.

This graduate capability is supported by:

Learning outcomes

- Have an appreciation of the impact of relativity theory on our understanding of the nature of space and time.
- Working knowledge of the Lagrangian mechanics, calculus of variations and differential geometric concepts, particularly in their application to relativistic physics and technology.
- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.

Assessment tasks

- Assignments: approx weekly
- 1 mid-session test, 50 min
- Final examination

Effective Communication

We want to develop in our students the ability to communicate and convey their views in forms effective with different audiences. We want our graduates to take with them the capability to read, listen, question, gather and evaluate information resources in a variety of formats, assess, write clearly, speak effectively, and to use visual communication and communication technologies as appropriate.

This graduate capability is supported by:

Learning outcomes

- Gain experience in relating abstract concepts that underline the special and general theories of relativity to the appropriate mathematical tools and their applications to concrete problems.
- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Assessment tasks

- Assignments: approx weekly

- 1 mid-session test, 50 min
- Final examination

Socially and Environmentally Active and Responsible

We want our graduates to be aware of and have respect for self and others; to be able to work with others as a leader and a team player; to have a sense of connectedness with others and country; and to have a sense of mutual obligation. Our graduates should be informed and active participants in moving society towards sustainability.

This graduate capability is supported by:

Learning outcome

- Develop an appreciation of the astrophysical applications of special and general relativity and gain working knowledge of some of the standard techniques.

Feedback

Student Liaison Committee

The Physics Department values quality teaching and engages in periodic student evaluations of its units, external reviews of its programs and course units, and seeks formal feedback from students via focus groups and the Student Liaison Committee. Please consider being a member of this committee, which meets once during the semester (lunch provided), with the purpose of improving teaching via student feedback. The class will be asked to nominate two students as representatives for the ASTR378 unit on the student liaison committee. This nomination process will be conducted during lectures and the lecturer will forward the names to the Head of Department. The SLC meetings are minuted and student representatives receive copies of the minutes from the two preceding SLC meetings prior to the meeting. An update on the responses that have been made by the department to the feedback obtained at the two preceding SLC meetings are reported by the Head of Department at the beginning of each SLC meeting. These responses are also minuted. The feedback is acted upon in a number of ways mostly initiated via Department of Physics and Astronomy meetings, where decisions on actions are taken. This is the first year of our new 3xx level program, so you feedback will be very important.

Standards Expectation

Grading

An aggregate standard number grade (SNG) corresponding to a pass (P) is required to pass this unit.

High Distinction (HD, 85-100%): provides consistent evidence of deep and critical understanding in relation to the learning outcomes. There is substantial originality and insight in identifying, generating and communicating competing arguments, perspectives or problem solving approaches; critical evaluation of problems, their solutions and their implications; creativity in application.

Distinction (D, 75-84%): provides evidence of integration and evaluation of critical ideas, principles and theories, distinctive insight and ability in applying relevant skills and concepts in relation to learning outcomes. There is demonstration of frequent originality in defining and analysing issues or problems and providing solutions; and the use of means of communication appropriate to the discipline and the audience.

Credit (Cr, 66-74%): provides evidence of learning that goes beyond replication of content knowledge or skills relevant to the learning outcomes. There is demonstration of substantial understanding of fundamental concepts in the field of study and the ability to apply these concepts in a variety of contexts; plus communication of ideas fluently and clearly in terms of the conventions of the discipline.

Pass (P, 50-65%): provides sufficient evidence of the achievement of learning outcomes. There is demonstration of understanding and application of fundamental concepts of the field of study; and communication of information and ideas adequately in terms of the conventions of the discipline. The learning attainment is considered satisfactory or adequate or competent or capable in relation to the specified outcomes.

Fail (F, 0-49%): does not provide evidence of attainment of all learning outcomes. There is missing or partial or superficial or faulty understanding and application of the fundamental concepts in the field of study; and incomplete, confusing or lacking communication of ideas in ways that give little attention to the conventions of the discipline.