Honours General Relativity Course, 2018

Hello, and welcome to all Physics Honours students taking the General Relativity elective unit in Semester 1, 2018!

In this unit we'll discuss one of the crowning achievements of modern physics: the General Theory of Relativity (GR). GR may be a century old, but has never been more relevant than today, as many of its predictions – such as black holes, the expansion of the Universe and gravitational waves – are becoming observable for the first time.

GR is viewed as "difficult" – even by Einstein himself! – because of its counter-intuitive concepts and its mathematical notation. I would like us to experience the power of this mathematics, but I don't want to begin the course with 10 lectures on differential geometry! I therefore plan to develop the physics and mathematics simultaneously, and that we will practice the mathematics in more familiar settings – such as Special Relativity, Electromagnetism and in 2D spaces – before applying it to the 4D spacetime of GR.

In my view, we learn physics best not when listening to a lecturer, but when thinking about the concepts and writing the mathematics ourselves. I will therefore suggest that we spend much of our class time in this active mode, and I have prepared a Workbook to accompany the unit that we will be using in each class.

Please do not hesitate to get in touch with me at any time. My contact details are: e-mail cblake@swin.edu.au, phone 9214 8624, office AR303. I look forward to working with you all this semester.

Content

We will have 12 classes, each of 2 hours, taking place on Tuesdays 10.30-12.30 in ATC601c and Fridays 9.30-11.30 in ATC421. Each class will combine different elements of lectures and tutorials in an active-learning setting. We will divide the content into 3 sections, shown below. Please see the end of this document for a more detailed week-by-week schedule.

Section A: Relativistic Physics	Class 1: Special Relativity
	Class 2: Index notation
	Class 3: Electromagnetism
	Class 4: Accelerated motion
Section B: Gravity and Curvature	Class 5: Equivalence principle
	Class 6: Curved space and metrics
	Class 7: Geodesics
	Class 8: Tensors
Section C: Black Holes and the Universe	Class 9: Black holes
	Class 10: Einstein equation
	Class 11: Cosmology
	Class 12: Revision/consolidation

Intended Learning Outcomes

The intended learning outcomes of this unit are that students should be able to:

- Describe the fundamental concepts of General Relativity, such as the Equivalence Principle, gravitational time dilation, the motion of particles along geodesics in curved space-time, and the connection of space-time curvature to matter-energy.

- Use tensor index notation to evaluate mathematical expressions, including basic applications to Special Relativity, Electromagnetism, and General Relativity.

- Analyse geometry in curved spaces using the metric, including the evaluations of distances, areas, local curvature and co-ordinate transformations.

- Apply the principles of General Relativity to solve physical problems related to gravitational effects near the surface of the Earth, near a black hole, and in the expanding Universe.

Assessment

Similar to the other Honours units, 40% of the final grade for this unit is in the form of homework problem sets described below, and 60% is associated with a final test.

Homework problems

We only learn physics after studying some homework problems. We will study five short problem sets, P1-P5, which will also form the continuous assessment for this unit.

Given the daunting nature of GR, we will use an evaluation scheme – which I have borrowed from Thomas A. Moore of Ponoma College, whose excellent GR textbook you can find listed below – emphasizing initial effort and understanding after discussion in class, rather than getting everything right the first time.

Each Friday I will hand out a short problem set (see schedule below), which I ask you to try before the following Friday's class. In that class, I will hand out solutions to the problem set and ask you to correct your work using a different coloured pen. We will allow plenty of time for discussing particular difficulties with the problems. At the end of the class, you will hand in this problem set and I will evaluate it.

I understand that Honours year is particularly busy, and many issues can arise in life. Therefore, the final problem set grade will exclude the lowest score, so you can drop one of the problem sets without any consequence.

The evaluation scheme for the problem sets works as follows:

Initial Effort (regardless of correctness!)	4	Satisfactory initial effort
	3	Some missing explanations or steps
	2	Significant problem parts missing
	1	Little coherent effort
	0	No initial effort

Correction Quality	3	Solution is correct
	2	Minor issues were not corrected
	1	Major issues were not corrected
	0	No correction effort

Correction Needed	3	No correction was necessary
	2	Minor corrections were needed
	1	Major corrections were needed
	0	Initial effort needed a complete re-write

The initial effort mark has nothing to do with whether that effort is correct. For example, if you make a good but incorrect stab at all the questions before class, and then fully correct your work, you can earn up to 7 points.

Textbooks

There is no set textbook for the course, but here are some recommendations. My favourite introductory textbook for learning General Relativity – and the book on which I have based the course style most closely – is:

A General Relativity Workbook by Thomas A. Moore

This book should be available in the Swinburne library and bookstore. Other useful textbooks are:

A First Course in General Relativity by Bernard Schutz
An Introduction to Einstein's General Relativity by James B. Hartle
Spacetime and Geometry: An Introduction to General Relativity by Sean M. Carroll

The internet contains many useful and freely available sets of notes on General Relativity. A few examples I have consulted in preparing the course (with thanks to the authors for providing them!):

http://web.physics.ucsb.edu/~marolf/MasterNotes.pdf
https://www.physics.mcmaster.ca/~cburgess/GRcourse/GRnotes.pdf
http://www.damtp.cam.ac.uk//user/eal40/teach/GR/GR.pdf
http://star-www.st-and.ac.uk/~hz4/gr/HeavensGR.pdf
http://eagle.phys.utk.edu/guidry/astro616/lectures/lecture_ch18.pdf

Schedule

The following is the detailed week-by-week schedule of the unit. Classes will take place in room ATC601c (Tuesdays) and ATC421 (Fridays). Weeks refer to normal Swinburne semester weeks.

Week 9	**Tues 1 May** 10.30-12.30 ATC601c	Class 1: Special Relativity	
	Fri 4 May 9.30-11.30 ATC421	Class 2: Index notation	Hand out P1
Week 10	**Tues 8 May** 10.30-12.30 ATC601c	Class 3: Electromagnetism	
	Fri 11 May 9.30-11.30 ATC421	Class 4: Accelerated motion	Discuss & hand in P1 Hand out P2
Week 11	**Tues 15 May** 10.30-12.30 ATC601c	Class 5: Equivalence principle	
	Fri 18 May 9.30-11.30 ATC421	Class 6: Curved space and metrics	Discuss & hand in P2 Hand out P3
Week 12	**Tues 22 May** 10.30-12.30 ATC601c	Class 7: Geodesics	
	Fri 25 May 9.30-11.30 ATC421	Class 8: Tensors	Discuss & hand in P3 Hand out P4
	Tues 29 May 10.30-12.30 ATC601c	Class 9: Black holes	
	Fri 1 June 9.30-11.30 ATC421	Class 10: Einstein equation	Discuss & hand in P4 Hand out P5
	Tues 5 June 10.30-12.30 ATC601c	Class 11: Cosmology	
	Fri 8 June 9.30-11.30 ATC421	Class 12: Revision	Discuss & hand in P5
	11-17 June	Test revision period	
	18-24 June	Tests held	