SEMESTER LEARNING ACTIVITY PLANS (SLAP)
SEMESTER ODD 2022/2023

General Theory of Relativity

MFF5041 / 3 Credits

Lecturer Coordinator:

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UNIVERSITAS GADJAH MADA
FACULTY OF MATHEMATICS AND NATURAL SCIENCE
2022

	Universitas Gadjah Mada Faculty of Mathematics and Natural Science Physics Department / Study Program Master Physics Semester Odd 2022/2023

SEMESTER LEARNING ACTIVITY PLANS (SLAP)

Code	Course Name	Credits (credits)	Semester	Status	Prerequisite
MFF5041	*General Theory of Relativity*	*3*	*Odd*	*Elective*	*None*

Short Description	General Theory of Relativity course is Elective course 3 credits (Theory) in the 2022 Curriculum Master Physics Study Program, Faculty of Mathematics and Natural Science UGM. The syllabus of this course is as follows: 1. Special relativity theory: Einstein's postulates for special relativity, Lorentz transformation, Minkowski space, cone of space-time and causality, worldline, self-time, observers. 2. Principle of equivalence and covariance: weak equivalence principle, equivalence principle, Einstein equivalence principle, covariance principle, the effect of the equivalence principle. 3. Diversity Theory: maps and atlases, maximum atlases, differential structures, smooth variances, curves and functions, tangent vectors and companion tangent vectors, tangent spaces and companion tangent spaces, vector fields and companion vector fields, Lie derivative curves and Lie brackets, algebraic fundamentals base for tensor, tensor fields, tensor interpretation, local bases, tensor component, tensor variety transfer, tensor products, contraction, Lie derivative, tensor derivative, differential form, symmetric bilinear form. 4. Semi-Riemannian diversity: metric tensor, isometry, metric index, Levi-Civita connection, parallel shift, covariance derivative, geodesic and geodesic equations, exponential mapping, Riemann curvature, frame plane, Ricci curvature, and Ricci scalars. 5. Energy, matter, gravity, and geometry: energy and momentum tensor, momentum energy tensor for some cases: dust, perfect flow of matter, classical field equations, the relationship between space-time geometry with energy and matter, the relationship between space-time curvature and matter dynamics. 6. Einstein's field equations, Einstein's field equations formulation, properties of Einstein's field equations, Schwarzschild's Answer. The courses are held in class for 14 weeks, each week's session last for 3 x 50 minutes. Four weeks of course period is used for Midterm Exam and Final Exam, each held for two weeks as scheduled. Student evaluation for course assessments is performed summative and formative. The summative evaluation is implemented as written exams, both Midterm and Final Exam, which take a maximum of 120 minutes. The formative evaluation is implemented as individual assignments for each student in the form of completing an assignment individually. Monitoring is carried out by observing student activities during the course, such as attendance, Q&A and discussion about the material presented, and student performance in completing individual assignments.
Program Learning Outcomes (PLO) Imposed on the Course	PLO 3: Mastering further knowledge of classical and modern physics theory, and its relationship with other disciplines, and has mastered an advanced field of physics specialization that allows him to keep up with the latest international research developments. PLO 4: Mastering various mathematical disciplines related to an advanced field of physics, and able to develop physical models using various mathematical and

		computational tools with an inter or multidisciplinary approach to solving problems related to an advanced field of physics.
	PLO 6	Able to apply knowledge to analyze, synthesize, formulate problems and solve problems comprehensively in one of advanced field of physics, through experimental or theoretical research, then be able to classify and draw conclusions about their findings for the development of science and technology.
Course Outcomes (CO)	**Upon completion of this course, students should be able to:**	
	CO1	Understand the theory of special relativity: Einstein's postulates for special relativity, Lorentz transformations, Minkowski space, cones of space-time and causality, world lines, self-time, observers, Equivalence and covariance principles, weak equivalence principle, equivalence principle, Einstein equivalence principle, covariance principle, the effect of the principle of equality.
	CO2	Understand Diversity Theory, maps and atlases, maximum atlases, differential structures, smooth variance, curves and functions, tangent vectors and companion tangent vectors, tangent spaces and companion tangent spaces, vector fields and companion vector fields, Lie derivative curves and Lie brackets, algebraic fundamentals basis for tensor, tensor field, tensor interpretation, local base, tensor component.
	CO3	Understand the transfer of tensor varieties, tensor products, contractions, Lie derivatives, tensor derivatives, differential forms, and symmetrical bilinear forms. Semi-Riemannian diversity: metric tensors, isometry, metric index, Levi-Civita connections, parallel shifts, covariance derivatives, geodesic and geodesic equations, exponential mapping, Riemann curvature, frame fields, Ricci curvature, and Ricci scalars.
	CO4	Understand energy, matter, gravity, and geometry: energy and momentum tensor, momentum energy tensor for some cases: dust, perfect flow of matter, classical field equations, the relationship between space-time geometry with energy and matter, the relationship between space-time curvature and matter dynamics.
	CO5	Understand Einstein's field equations, Einstein's field equations formulation, properties of Einstein's field equations, Schwarzschild's Answer.
	CO6	
	CO7	
	CO8	

The Correlation of CO to Learning Materials and Methods, and Time Allocation		**Learning Materials**	**Learning Methods**	**Time Allocation**
	CO1	Review of special relativity: Einstein postulate in special relativity, transformasi Lorentz.	Lecture, discussion	3 x 50 minutes
	CO1	Minkowski space, cone of spacetime and causality, world line, self-time, observer.	Lecture, discussion	3 x 50 minutes
	CO1	The principle of equality and covariance: the weak equivalence principle, the equivalence principle, the Einstein equivalence principle,	Lecture, discussion	3 x 50 minutes

		the covariance principle, the effect of the equivalence principle.		
	CO2	Diversity Theory: maps and atlases, maximum atlases, differential structures, slippery diversity.	Lecture, discussion	3 x 50 minutes
	CO2	Pengenalan dan interpretasi aspek formal perumusan mekanika kuantum tentang: • rapat kebolehjadian menemukan partikel, • harga harap suatu besaran fisis, • ketidakpastian pengukuran besaran fisis dan konsep ketidakpastian Heisenberg.	Lecture, discussion	3 x 50 minutes
	CO2	Lie derivative curves and Lie brackets, algebraic basics for tensor, tensor field, tensor interpretation, local basis, tensor components.	Lecture, discussion	3 x 50 minutes
	CO2	Variation of tensor, tensor product, contraction, Lie derivative, tensor derivative, differential form, symmetrical bilinear form.	Lecture, discussion	3 x 50 minutes
	CO3	Semi-Riemannan diversity: metric tensor, isometry, metric index, Levi-Civita connection, parallel shift.	Lecture, discussion	3 x 50 minutes
	CO3	Covariance derivatives, geodesic and geodesic equations, exponential mapping, Riemann curvature, skeleton field, Ricci curvature and Ricci scalars.	Lecture, discussion	3 x 50 minutes
	CO3	Energy, matter, gravity and geometry: energy and momentum tensors, momentum energy tensors for some cases: dust, perfectly flowing substances, classical field equations.	Lecture, discussion	3 x 50 minutes
	CO4	The relationship between space-time geometry and energy and Theory.	Lecture, discussion	3 x 50 minutes
	CO4	The relationship between the curvature of spacetime and the dynamics of matter.	Lecture, discussion	3 x 50 minutes
	CO4	Einstein's field equations: formulation of Einstein's field equations, properties of Einstein's field equations.	Lecture, discussion	3 x 50 minutes
	CO4	Schwarzschild spacetime.	Lecture, discussion	3 x 50 minutes

	Final Exam/ Project Task Results/ Case Analysis Results
Learning Methods	Lecture, discussion
Student Learning Experience	Learn to analyze and review: Review of special relativity: Einstein postulate in special relativity, transformasi Lorentz., Minkowski space, cone of spacetime and causality, world line, self-time, observer., The principle of equality and covariance: the weak equivalence principle, the equivalence principle, the Einstein equivalence principle, the covariance principle, the effect of the equivalence principle. , Diversity Theory: maps and atlases, maximum atlases, differential structures, slippery diversity., Pengenalan dan interpretasi aspek formal perumusan mekanika kuantum tentang: • rapat kebolehjadian menemukan partikel, • harga harap suatu besaran fisis, • ketidakpastian pengukuran besaran fisis dan konsep ketidakpastian Heisenberg., Lie derivative curves and Lie brackets, algebraic basics for tensor, tensor field, tensor interpretation, local basis, tensor components., Variation of tensor, tensor product, contraction, Lie derivative, tensor derivative, differential form, symmetrical bilinear form., Semi-Riemannan diversity: metric tensor, isometry, metric index, Levi-Civita connection, parallel shift., Covariance derivatives, geodesic and geodesic equations, exponential mapping, Riemann curvature, skeleton field, Ricci curvature and Ricci scalars., Energy, matter, gravity and geometry: energy and momentum tensors, momentum energy tensors for some cases: dust, perfectly flowing substances, classical field equations., The relationship between space-time geometry and energy and Theory., The relationship between the curvature of spacetime and the dynamics of matter., Einstein's field equations: formulation of Einstein's field equations, properties of Einstein's field equations., Schwarzschild spacetime..
Access to Learning Media/ LMS and Offline and Online Percentage	Sync (google meet), Asynchronous (google classroom, video)
Assessment Methods and Synchronization with CO	(see table below)

Assessment Methods	**Assessment Percentage**	**Criteria/Indicators**	**CO1**	**CO2**	**CO3**	**CO4**
Participatory Activity*						
Project Results/ Case Study Results/ PBL Results*						
Cognitive						
Assignment	30%		7,5%	7,5%	7,5%	7,5%
Quiz						
Midterm Exam	35%		17,5%	17,5%		
Final Exam	35%				17,5%	17,5%

*) can also be obtained from the Midterm or Final Exam as the result of participatory activities or project/ case study results. According to IKU 7, the percentage of project results/ case study/ PBL results is at least 50%.

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<tr><td rowspan="2">References</td><td colspan="4">Main references:
Carroll S., 2004, Spacetime and Geometry. An Introduction to General Relativity, Addison-Wesley, New York.</td></tr>
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<tr><td>Lecturers (Team Teaching)</td><td colspan="4">1. Dr. Arief Hermanto, Drs., S.U., M.Sc.
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<tr><td rowspan="2">Authorization</td><td>Date of Drafting</td><td>Lecturer Coordinator</td><td>Head of Curriculum Committee</td><td>Head of Study Program</td></tr>
<tr><td></td><td>Dr. Arief Hermanto, Drs., S.U., M.Sc.</td><td>Dr.Ing. Ari Setiawan</td><td>Mirza Satriawan, M.Si., Ph.D</td></tr>
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