Politechnika Krakowska
im. Tadeusza Kościuszki

Karta przedmiotu

obowiązuje studentów rozpoczynających studia w roku akademickim 2020/2021

Wydział Inżynierii Materiałowej i Fizyki

Kierunek studiów: Fizyka Techniczna w Języku Angielskim   Profil: Ogólnoakademicki

Forma sudiów: stacjonarne   Kod kierunku: FTja

Stopień studiów: II

Specjalności: Computer modelling (modelowanie komputerowe w języku angielskim)

1 Informacje o przedmiocie

Nazwa przedmiotu	Geometric methods in physics
Nazwa przedmiotu w języku angielskim	Geometric methods in physics
Kod przedmiotu	WIMiF FTJA oIIS C3 20/21
Kategoria przedmiotu	Przedmioty kierunkowe
Liczba punktów ECTS	2.00
Semestry	2

2 Rodzaj zajęć, liczba godzin w planie studiów

Semestr	Wykład	Ćwiczenia	Laboratorium	Laboratorium komputerowe	Seminarium	Projekt
2	15	0	0	15	0	0

3 Cele przedmiotu

Cel 1 Main aim of this course is to introduce modern mathematical language that will help student to analyze contemporary problems in physics and technology including: nonlinear phenomena, classical field theory, dynamical systems and geometry of physics.

4 Wymagania wstępne w zakresie wiedzy, umiejętności i innych kompetencji

1 Linear algebra

2 Differential and Integral Calculus

3 General Physics

5 Efekty kształcenia

EK1 Wiedza Student knows basic (linear and nonlinear) models in physics.

EK2 Umiejętności Student knows methods of analysis of basic (linear and nonlinear) models in physics.

EK3 Wiedza Student knows advanced mathematical tools used for describing nonlinear phenomena and used in theoretical physics.

EK4 Umiejętności Student can use advanced mathematical tools for describing nonlinear phenomena and used in theoretical physics.

EK5 Kompetencje społeczne Student can work in groups on independent research project.

6 Treści programowe

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
K1	1. Lagrangian and Hamiltonian Mechanics (reminder) Reminder of basic notions of Lagrangian and Hamiltonian mechanics: general coordinates, velocity, index notation, kinetic and potential energy, Lagrangian, Euler-Lagrange equations of motion, momentum, small oscillations, Hamiltonian, Hamiltonian equations of motion. Worked out example: small oscillations for double pendulum and its eigenmodes.	1
K2	2. Basic notions of classical field theory Notion of a field. Introduction to Calculus of Functionals: functional, Dirac delta, functional derivative. Action as functional and its variation. Euler-Lagrange equations for fields. Conjugate momenta. Hamiltonian. Noether theorem associated with symmetries and Energy-Momentum tensor. Worked out examples: Klein-Gordon equation, Schrodinger equation.	1
K3	3. Relativistic fields part 1 Minkowski spacetime as affine space. Minkowski metric. Spacetime interval. Isometries of Minkowski metric as Lorentz transformations: rotations and boosts. Spacetime algebra formulation of Lorentz transformations. Energy-momentum conservation in Minkowski spacetime. SL(2,C) as covering of Lorentz group and spinor representations, gamma matrices and their properties. Chriality operator.	1
K4	4. Relativistic fields part 2 Worked out models: Lagrangians that preserves chirality- chiral models. Sigma models as starting point for Standard Models. Dirac equation and Weyl equation.	1
K5	5. Nonlinear and collective phenomena Worked out example: Instanton in a double-well potential. Worked out example: Kortewegde Vries equation and soliton.	1

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
K6	6. Spontaneous symmetry breaking Goldston theorem and explanation of appearance of Higgs boson. Example of spontaneous symmetry breaking in simple model.	1
K7	7. Manifolds Manifolds in Euclidean space. Inverse and implicit function theorems. Manifold defined as inverse image of mapping. Change of coordinates. Examples: Euclidean space, sphere, Real and Complex Projective space, configuration space of simple mechanical systems.	1
K8	8. Tangent space Functions on manifold. Hadamard lemma. Tangent vectors as differential operators. Change of coordinates. Tangent bundle as an example of vector bundle. Mapping between tangent bundles as an example of bundle map. Push-forward. Lagrangian as a functional on tangent bundle.	1
K9	9. Vector fields Module of vector fields. Flow of a vector field. Straightening flow theorem. Lie derivative of a vector field. Vector fields as a Lie algebra Lie bracket. Regular and singular points. Linear flows on R2 -node improper/proper, sink. Hyperbolic points and Hartmans theorem on linearizion. Lipschitz's condition and uniqueness of solutions are equations of physics unique? Basic notion of Lie groups and Lie algebras.	1
K10	10. Cotangent space Dual space to a vector space. Differential forms. Transformation properties. Momentum as a covector. Cotangent bundle as a vector bundle. Examples. Lie derivative of forms.	1
K11	11. Cotangent bundle Wedge product on simple forms. Exterior derivative. Pullback. Examples. Vector analysis vs Exterior calculus. Lagrangian and Poincare form.	1
K12	12. Integration Poincare lemma, homotopy and homotopy operator. Stokes theorem. Boundary operator and chains.	1
K13	13. Metric geometry Metric and Riemann geometry. Isometries. General notion of tensor as multilinear function universal property. Coordinates of tensor. Connection, covariant derivative, torsion and curvature.	1
K14	14. Electrodynamics in exterior calculus Integral and differential form of Maxwell equations. Hodge star. F-tensor. Sources. Gauge freedom.	1
K15	15. Preparation of Students talks on selected topics.	1

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W1	1. Lagrangian and Hamiltonian Mechanics (reminder) Reminder of basic notions of Lagrangian and Hamiltonian mechanics: general coordinates, velocity, index notation, kinetic and potential energy, Lagrangian, Euler-Lagrange equations of motion, momentum, small oscillations, Hamiltonian, Hamiltonian equations of motion. Worked out example: small oscillations for double pendulum and its eigenmodes.	1
W2	2. Basic notions of classical field theory Notion of a field. Introduction to Calculus of Functionals: functional, Dirac delta, functional derivative. Action as functional and its variation. Euler-Lagrange equations for fields. Conjugate momenta. Hamiltonian. Noether theorem associated with symmetries and Energy-Momentum tensor. Worked out examples: Klein-Gordon equation, Schrodinger equation.	1
W3	3. Relativistic fields part 1 Minkowski spacetime as affine space. Minkowski metric. Spacetime interval. Isometries of Minkowski metric as Lorentz transformations: rotations and boosts. Spacetime algebra formulation of Lorentz transformations. Energy-momentum conservation in Minkowski spacetime. SL(2,C) as covering of Lorentz group and spinor representations, gamma matrices and their properties. Chriality operator.	1
W4	4. Relativistic fields part 2 Worked out models: Lagrangians that preserves chirality- chiral models. Sigma models as starting point for Standard Models. Dirac equation and Weyl equation.	1
W5	5. Nonlinear and collective phenomena Worked out example: Instanton in a double-well potential. Worked out example: Kortewegde Vries equation and soliton.	1
W6	6. Spontaneous symmetry breaking Goldston theorem and explanation of appearance of Higgs boson. Example of spontaneous symmetry breaking in simple model.	1
W7	7. Manifolds Manifolds in Euclidean space. Inverse and implicit function theorems. Manifold defined as inverse image of mapping. Change of coordinates. Examples: Euclidean space, sphere, Real and Complex Projective space, configuration space of simple mechanical systems.	1
W8	8. Tangent space Functions on manifold. Hadamard lemma. Tangent vectors as differential operators. Change of coordinates. Tangent bundle as an example of vector bundle. Mapping between tangent bundles as an example of bundle map. Push-forward. Lagrangian as a functional on tangent bundle.	1
W9	9. Vector fields Module of vector fields. Flow of a vector field. Straightening flow theorem. Lie derivative of a vector field. Vector fields as a Lie algebra Lie bracket. Regular and singular points. Linear flows on R2 -node improper/proper, sink. Hyperbolic points and Hartmans theorem on linearizion. Lipschitz's condition and uniqueness of solutions are equations of physics unique? Basic notion of Lie groups and Lie algebras.	1

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W10	10. Cotangent space Dual space to a vector space. Differential forms. Transformation properties. Momentum as a covector. Cotangent bundle as a vector bundle. Examples. Lie derivative of forms.	1
W11	11. Cotangent bundle Wedge product on simple forms. Exterior derivative. Pullback. Examples. Vector analysis vs Exterior calculus. Lagrangian and Poincare form.	1
W12	12. Integration Poincare lemma, homotopy and homotopy operator. Stokes theorem. Boundary operator and chains.	1
W13	13. Metric geometry Metric and Riemann geometry. Isometries. General notion of tensor as multilinear function universal property. Coordinates of tensor. Connection, covariant derivative, torsion and curvature.	1
W14	14. Electrodynamics in exterior calculus Integral and differential form of Maxwell equations. Hodge star. F-tensor. Sources. Gauge freedom.	1
W15	15. Students talks on selected topics.	1

7 Narzędzia dydaktyczne

N1 Wykłady

N2 Dyskusja

N3 Praca w grupach

N4 Konsultacje

8 Obciążenie pracą studenta

Forma aktywności	Średnia liczba godzin na zrealizowanie aktywności
Godziny kontaktowe z nauczycielem akademickim, w tym:	
Godziny wynikające z planu studiów	30
Konsultacje przedmiotowe	0
Egzaminy i zaliczenia w sesji	0
Godziny bez udziału nauczyciela akademickiego wynikające z nakładu pracy studenta, w tym:	
Przygotowanie się do zajęć, w tym studiowanie zalecanej literatury	15
Opracowanie wyników	0
Przygotowanie raportu, projektu, prezentacji, dyskusji	5
Sumaryczna liczba godzin dla przedmiotu wynikająca z całego nakładu pracy studenta	**50**
Sumaryczna liczba punktów ECTS dla przedmiotu	2.00

9 Sposoby oceny

A1: Homeworks and exercises: Student is required to work out simple exercises given during the lectures. A2: Final project: Student is required to prepare a presentation on one of the subjects connected with the subject. Final grade = Average(Average(A1) + Average(A2))

Ocena formująca

F1 A1: Homeworks and exercises

F2 A2: Final project

Ocena podsumowująca

P1 Final grade = Average(Average(A1) + Average(A2))

Warunki zaliczenia przedmiotu

W1 Final grade > 2

Kryteria oceny

Efekt kształcenia 1	
Na ocenę 2.0	Student does not know basic (linear and nonlinear) models in physics.

Na ocenę 3.0	Student understands idea of Lagrange and Hamiltonian formulations of nonlinear models.
Na ocenę 3.5	In addition, Student knows specific examples of nonlinear models.
Na ocenę 4.0	In addition, Student know methods that can provide some solutions to specific models.
Na ocenę 4.5	In addition, Student knows general idea behind specific models.
Na ocenę 5.0	In addition, Student can explain principles of use of various tools and methods to analyze specific models and can generalize them to larger class of phenomena.
Efekt kształcenia 2	
Na ocenę 2.0	Student does not know methods of analysis of basic (linear and nonlinear) models in physics.
Na ocenę 3.0	Student can use Lagrange and Hamiltonian formalism.
Na ocenę 3.5	In addition, Student can analyse specific examples of nonlinear models.
Na ocenę 4.0	In addition, Student can use methods that can provide some solutions to specific models.
Na ocenę 4.5	In addition, Student can use in analysis general idea behind specific models.
Na ocenę 5.0	In addition, Student can use of various tools and methods to analyze specific models and can generalize them to larger class of phenomena.
Efekt kształcenia 3	
Na ocenę 2.0	Student does not know advanced mathematical tools used for describing nonlinear phenomena and used in theoretical physics.
Na ocenę 3.0	Student knows specific tools that can be used to analysis specific nonlinear model.
Na ocenę 3.5	In addition, Student knows genera theory of specific mathematical tools.
Na ocenę 4.0	In addition, Student knows number of various nonlinear models and mathematical tools applied to them.
Na ocenę 4.5	In addition, Student knows differential geometry at the level sufficient to describe simple phenomena in physics.
Na ocenę 5.0	In addition, Student knows adavnced matematical tools that can be applied in description of nonlinear phenomena.
Efekt kształcenia 4	
Na ocenę 2.0	Student cannot advanced mathematical tools used for describing nonlinear phenomena and used in theoretical physics.
Na ocenę 3.0	Student can use specific tools that can be applied to analysis specific nonlinear model.
Na ocenę 3.5	In addition, Student can use genera theory of these mathematical tools.

Na ocenę 4.0	In addition, Student can write down number of various nonlinear models and can apply mathematical tools to solve them.
Na ocenę 4.5	In addition, Student can use differential geometric methods to simple phenomena in physics.
Na ocenę 5.0	In addition, Student knows how to apply adavnced matematical tools in description of nonlinear phenomena.
Efekt kształcenia 5	
Na ocenę 2.0	Student cannot work in group and does not know how to search information on specific problems.
Na ocenę 3.0	Student can work in group and knows how to search information on specific problems.
Na ocenę 3.5	Student can work in group and knows how to search information on specific problems.
Na ocenę 4.0	Student can work in group and knows how to search information on specific problems.
Na ocenę 4.5	Student can work in group and knows how to search information on specific problems.
Na ocenę 5.0	Student can work in group and knows how to search information on specific problems.

10 Macierz realizacji przedmiotu

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK1	K_W01b K_W06	Cel 1	W1 W2 W3 W5 W6 W7 W8 W9 W10 W11 W12 W13 W14	N1 N2 N3 N4	F1 F2 P1
EK2	K_U01b K_U02 K_U03b K_U04b K_U07b	Cel 1	K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12 K13 K14 K15	N2 N3 N4	F1 F2 P1

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK3	K_W01b	Cel 1	W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 W11 W12 W13 W14	N1 N2 N4	F1 F2 P1
EK4	K_U01b K_U02 K_U03b K_U04b K_U07b	Cel 1	K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12 K13 K14 K15 W15	N2 N3 N4	F1 F2 P1
EK5	K_K01 K_K03	Cel 1	K15 W15	N2 N3 N4	F1 F2 P1

11 Wykaz literatury

Literatura podstawowa

[1] **T. Frankel** — *Geometry of Physics*, Cambridge, 2011, Cambridge University Press

[2] **M. Dunajski** — *Solitons, Instantons, and Twistors*, Oxford, 2009, Oxford university Press

Literatura uzupełniająca

[1] **M. Nakahara** — *Geometry, Topology and Physics*, , 2003, CRC Press

[2] **R. Rajaraman** — *Solitons and Instantons*, , 1987, North Holland

12 Informacje o nauczycielach akademickich

Osoba odpowiedzialna za kartę

dr inż. Radosław Kycia (kontakt: `rkycia@pk.edu.pl`)

Osoby prowadzące przedmiot

1 dr Radosław Kycia (kontakt: `rkycia@pk.edu.pl`)

13 Zatwierdzenie karty przedmiotu do realizacji

(miejscowość, data) (odpowiedzialny za przedmiot) (dziekan)

Przyjmuję do realizacji (data i podpisy osób prowadzących przedmiot)

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