6. MO18-5202 Advanced Fluid Mechanics

Module name	Advanced Fluid Mechanics
Module level, if applicable	Master
Code, if applicable	MO18-5202
Subtitle, if applicable	-
Course, if applicable	Advanced Fluid Mechanics
Semester	2nd Semester
Person responsible for the module	Suntoyo, S.T., M.Eng., Ph.D.
Lecturer	Suntoyo, S.T., M.Eng., Ph.D.
Language	Indonesian
Relation to curriculum	Mandatory course for master degree program in Ocean Engineering, 2nd semester.
Type of teaching, contact hours	Lecture, <50 students 150 minutes x 16 weeks per semester
Workload	4. Class, 3 × 50' = 150 minutes per week 5. Independent Study, 3 × 60' = 180 minutes per week 6. Structured Activities, 3 × 60' = 180 minutes per week
Credit points	3 CREDITS ~ 4.8 ECTS CREDITS × 1.6 ECTS
Requirements according to the examination regulations	A student must have attended at least 80% of the lectures to sit in the exams.
Recommended prerequisites	-

Learning outcomes **and their corresponding PLOs**	CLO.1. Able to understand the concept of boundary layer, fundamental flow, and basic equations of turbulent flow CLO.2. Able to understand the structure of turbulent boundary layer CLO.3. Able to understand the calculation of Drag and surface friction coefficient for boundary layer CLO.4. Able to calculate displacement and momentum thickness, momentum integral, analysis of integral laminar boundary layer and turbulent boundary layer	LO.4. Able to develop leadership attitudes, creativity, and communication skills in solving ocean engineering related problems
	CLO.5. Able to understand turbulence modeling with Reynold-stress equation, mixing-length model, two-equation model, and second-order closure. CLO.6. Able to estimate the point of instability and boundary layer transition.	
Content	This course discusses the concept of boundary layer, fundamental flow and the basic equations of turbulent flow, and discusses the structure of the turbulent boundary layer. Able to understand the calculation of Drag and surface friction coefficient for boundary layer. Able to calculate displacement and momentum thickness, momentum integral, analysis of integral laminar boundary layer and turbulent boundary layer. Able to understand turbulence modeling with Reynold-stress equation, mixing-length model, two-equation model, and second-order closure. Able to estimate the point of instability and boundary layer transitions.	
Study and examination requirements and forms of examination	7. In-class exercise 8. Assignment 9. Mid-term exam 10. Final exam	
Media employed	Offline: LCD, whiteboard, PowerPoint presentation Online: websites (myITS Classroom), Zoom, Microsoft Teams, PowerPoint presentation	

Reading list	1. White, FM, 1991, Viscous fluid flow, McGraw-Hill 2. Schlichting, H. and Gersten, K., 1999, Boundary layer theory, 8 th English Edition, Springer-Verlag 3. Pope, SB, 2000, Turbulent flows, Cambridge University Press 4. Wilcox, DC, 1998, Turbulence modeling for CFD, 2 nd Edition, DCW Industries 5. White, FM, 2002, Fluid mechanics, 5 th (International) Edition, McGraw-Hill

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Bahan Kajian	Dalam mata kuliah ini mahasiswa akan mempelajari pokok-pokok bahasan sebagai berikut: 1. Ikhtisar konsep boundary-layer: review konsep boundary-layer dengan menekankan pada teorema-teorema dan persamaan dasar boundary layer 2. Struktur turbulent boundary layer: Shear stress, skala panjang dan kecepatan, inner layer, outer layer, overlap layer- the log law, batas region-region, velocity-defect layer-Coles Layo of the wake, dan efek kekasaran 3. Drag/Hambatan: koefisien drag, boundary layer pada pelat datar, aliran dalam pipa, frictional head-loss pada aliran dalam pipa 4. Analisis integral pada turbulent boundary layer: Characteristic integral lengths, momentum-integral relation, aplikasi untuk aliran turbulen, dan aplikasi untuk aliran laminar 5. Pemodelan turbulensi: Efek turbulensi pada mean flow, model viskositas-Eddy, model transportasi Reynold-stress, dan model viskositas-Eddy nonlinier. 6. Instabilitas dan transisi: Persamaan Orr-Sommerfeld, stabilitas inviscid – persamaan Rayleigh, instabilitas viscous, instabilitas aliran tertentu, perpindahan dari instabilitas ke transisi, efek free-stream disturbances, prediksi rekayasa transisi, dan kendali transisi.
Study Materials	***The students will get the following materials:*** 1. ***Overview of boundary-layer concepts: review of boundary-layer concepts by emphasizing boundary layer theorems and basic equations*** 2. ***Turbulent boundary layer structure: Shear stress, scale length and velocity, inner layer, outer layer, overlap layer- the log law, region-region boundaries, velocity-defect layer-Coles Layo of the wake, and roughness effect*** 3. ***Drag/Resistance: drag coefficient, boundary layer on flat plate, flow in pipes, frictional head-loss on flow in pipes*** 4. ***Integral analysis on turbulent boundary layer: Characteristic integral lengths, momentum-integral relations, applications for turbulent flow, and applications for laminar flow*** 5. ***Turbulence modeling: Effect of turbulence on mean flow, Eddy-viscosity model , the Reynold-stress transport model, and the nonlinear Eddy-viscosity model.*** 6. ***Instability and transition: Orr-Sommerfeld equation, inviscid stability – Rayleigh equation, viscous instability, particular flow instability, transition from instability to transition, effects of free-stream disturbances, engineering prediction of transitions, and transition control.***

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CPL yang dibebankan MK ***PLO***	Mampu mengidentifikasi, merumuskan dan memecahkan masalah ilmu pengetahuan dan teknologi yang terkait dengan rekayasa kelautan melalui pendekatan teoritis, eksperimental, atau komputasi yang akurat dan inovatif ***Able to identify, formulize and solved the science and technology problems related to ocean engineering through the accurate and innovative theoretical, experimental, or computational approach***
CP-MK ***CLO***	1. Mampu memahami konsep boundary layer, aliran fundamental dan persamaan dasar aliran turbulen 2. Mampu memahami struktur turbulent boundary layer 3. Mampu memahami perhitungan Drag dan koefisien gesek permukaan untuk boundary layer 4. Mampu melakukan menghitung displacement dan momentum thickness, integral momentum, analisis integral laminar boundary layer dan turbulent boundary layer 5. Mampu memahami pemodelan turbulensi dengan persamaan Reynold-stress, model mixing-length, model two-equation, dan second-order closure. 6. Mampu mengestimasi titik instabilitas dan transisi boundary layer ***1. Able to understand the concept of boundary layer, fundamental flow and basic equations of turbulent flow*** ***2. Able to understand the structure of turbulent boundary layer*** ***3. Able to understand the calculation of Drag and surface friction coefficient for boundary layer*** ***4. Able to calculate displacement and momentum thickness, momentum integral, analysis of integral laminar boundary layer and turbulent boundary layer*** ***5. Able to understand turbulence modeling with Reynold-stress equation, mixing-length model, two-equation model, and second-order closure.*** ***6. Able to estimate the point of instability and boundary layer transition.***

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Perte-muan *Meeting*	**Kemampuan Akhir Sub CP-MK** *Final Ability*	**Keluasan (materi pembelajaran)** *Extent (learning material)*	**Metode Pembelajaran** *Learning methods*	**Estimasi Waktu** *Duration*	**Bentuk Evaluasi** *Evaluation Type*	**Kriteria dan Indikator Penilaian** *Assessment Criteria and Indicators*	**Bobot Penilaian** *Scoring*
1	Memahami dan mampu menjelaskan konsep dasar turbulent boundary layer, teorema-teorema, dan melakukan perhitungan persamaan dasar turbulent boundary layer *Able to understand and able to explain the basic concepts of the turbulent boundary layer, theorems, and calculate the basic equations of the turbulent boundary layer*	Konsep dasar turbulent boundary layer, teorema Prandtl dan d'Alembert, persamaan dasar turbulent boundary layer *Basic concepts of turbulent boundary layer, Prandtl and d'Alembert theorems, basic equations of turbulent boundary layer*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50'	Pertanyaan-pertanyaan langsung di kelas *Questions in class*	Ketepatan dan kedalaman dalam memberikan definisi uraian/ penjelasan tentang konsep dasar turbulent boundary layer berdasarkan teorema dan persamaan dasar aliran fluida *Accuracy and depth in providing the definition of the description/explanation of the basic concepts of the turbulent boundary layer based on the theorems and basic equations of fluid flow.*	
2	Memahami dan mampu menjelaskan inner layer, outer layer *Able to understand and explain the inner layer, outer layer*	Inner layer, outer layer *Inner layer, outer layer*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50'	Pertanyaan-pertanyaan langsung di kelas *Questions in class*	Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan struktur turbulent boundary layer *Accuracy and depth in providing a definition/description/explanation of the structure of the turbulent boundary layer*	

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3	Memahami dan mampu menjelaskan serta melakukan perhitungan dasar Shear stress, skala panjang dan kecepatan *Able to understand and be able to explain and perform basic calculations of shear stress, length and velocity scale*	Shear stress, skala panjang dan kecepatan *Shear stress, length scale and velocity*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Pertanyaan-pertanyaan langsung di kelas *Questions in class*	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan struktur turbulent boundary layer. 2. Ketepatan dalam melakukan perhitungan shear stress 1. *Accuracy and depth in providing definition/description/explanation of turbulent boundary layer structure* 2. *Accuracy in calculating shear stress*	
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4	Memahami dan mampu menjelaskan tentang konsep overlap layer- the log law dan batas region-region	Overlap layer- the log law, batas region-region	Paparan Contoh perhitungan Diskusi	3 × 50’	Pertanyaan-pertanyaan langsung di kelas	1. Ketepatandan kedalaman dalam memberikan definisi/ uraian/ penjelasan overlap layer- the log law dan batas region-region pada turbulent boundary layer 2. Ketepatan dalam melakukan perhitungan overlap layer- the log law	

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	Able to understand and explain the concept of overlapping layers- the log law and regional boundaries.	*Overlap layer- the log law, boundaries of regions*	*Presentation* *Calculation example* *Discussion*		*Questions in class*	*1. Accuracy and depth in providing definitions/descriptions/explanations of overlap layers- the log law and regional boundaries on the turbulent boundary layer* *2. Accuracy in calculating overlaps layer- the log law*	
5	Memahami dan mampu menjelaskan tentang konsep dasar hingga struktur turbulent boundary layer	Semua materi minggu 1-4	Papar an Diskusi	3 × 50’	Tugas kuliah	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang konsep dasar hingga struktur turbulent boundary layer 2. Ketepatan dalam menentukan shear stress	
	Able to understand and explain the inner layer, outer layer	*All materials in 1st-4th week*	*Presentation* *Discussion*		*Assignments*	*1. Accuracy and depth in providing a definition/description/explanation of the basic concepts to the structure of the turbulent boundary layer* *2. Accuracy in determining the shear stress*	
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6	Memahami dan mampu menjelaskan tentang konsep serta melakukan perhitungan velocity-defect layer-Coles Layo of the wake *Able to understand and explain the basic concepts to the structure of the turbulent boundary layer*	Velocity-defect layer-Coles Layo of the wake *Velocity-defect layer-Coles Layo of the wake*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Pertanyaan-pertanyaan langsung di kelas *Questions in class*	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan velocity-defect layer-Coles Layo of the wake 2. Ketepatan dalam melakukan perhitungan velocity-defect layer-Coles Layo of the wake 1. *Accuracy and depth in providing a definition/description/explanation of the basic concepts to the structure of the turbulent boundary layer* 2. *Accuracy in determining the shear stress*	
7	Memahami dan mampu menjelaskan tentang efek kekasaran, konsep gaya drag/ hambatan dan boundary layer pada pelat datar, serta melakukan perhitungan dasar terkait koefisien drag *Able to understand and be able to explain about the effect of roughness, the concept of drag/resistance force and boundary layer on a flat plate, as well as perform basic calculations related to the drag coefficient*	Efek kekasaran, Koefisien drag dan boundary layer pada pelat datar *Roughness effects, drag coefficients and boundary layers on flat plates*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Tugas kuliah *Assignments*	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan efek kekasaran, konsep gaya drag/ hambatan dan boundary layer pada pelat datar 2. Ketepatan dalam melakukan perhitungan dasar gaya dan koefisiean drag 1. *Accuracy and depth in providing a definition/description/explanation of the effect of roughness, the concept of drag/resistance and boundary forces layers on flat plates* 2. *Accuracy in performing basic calculations of drag forces and coefficients*	

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Perte-muan *Meeting*	**Kemampuan Akhir Sub CP-MK** *Final Ability*	**Keluasan (materi pembelajaran)** *Extent (learning material)*	**Metode Pembelajaran** *Learning methods*	**Estimasi Waktu** *Duration*	**Bentuk Evaluasi** *Evaluation Type*	**Kriteria dan Indikator Penilaian** *Assessment Criteria and Indicators*	**Bobot Penilaian** *Scoring*
8	Memahami dan mampu menjelaskan tentang konsep aliran dalam pipa dan *frictional head-loss* pada aliran dalam pipa serta melakukan perhitungan dasar terkait hal tersebut *Able to understand and be able to explain the concept of flow in pipes and frictional head-loss in flow in pipes and perform basic calculations related to these.*	Aliran dalam pipa dan frictional head-loss pada aliran dalam pipa *In-pipe flow and frictional head-loss on in-pipe flow*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Pertanyaan-pertanyaan langsung di kelas *Questions in class*	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang konsep aliran dalam pipa dan frictional head-loss pada aliran dalam pipa 2. Ketepatan dalam menentukan frictional head-loss pada aliran dalam pipa 1. *Accuracy and depth in providing a definition/description/explanation of the concepts of flow in pipes and frictional head-loss in flow. in the pipe* 2. *Accuracy in determining the frictional head-loss of flow in the pipe*	

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9	Mahasiswa mampu menjelaskan serta melakukan perhitungan untuk memecahkan persoalan kosep dasar turbulent boundary layer sampai dengan konsep aliran dalam pipa dan *frictional head-loss* pada aliran dalam pipa *Able to explain and perform calculations to solve the problem of the basic concept of turbulent boundary layer and the concept of flow in pipes and frictional head-loss in flow in pipes*	Semua materi minggu 1-8 *All materials in 1st-8th week*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Tugas kuliah *Assignments*	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan 2. Ketepatan dalam melakukan perhitungan sesuai dengan persoalan yang diberikan 1. *Accuracy and depth in providing definitions/descriptions/explanations* 2. *Accuracy in performing calculations according to the problems given*	

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10	Memahami dan mampu menjelaskan tentang teori characteristic integral-length serta melakukan perhitungan displacement thickness, momentum thickness, dan shape factor	Characteristic integral-length, displacement thickness, momentum thickness, dan shape factor	Paparan Contoh perhitungan Diskusi	3 × 50’	Tugas kuliah	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan teori characteristic integral-length 2. Ketepatan dalam melakukan perhitungan displacement thickness, momentum thickness, dan shape factor	

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	Able to understand and explain the characteristic integral-length theory and perform calculations of displacement thickness, momentum thickness, and shape factor	*In-pipe flow and frictional head-loss on in-pipe flow*	*Presentation* *Calculation example* *Discussion*		*Assignments*	*1. Accuracy and depth in providing a definition/description/explanation of characteristic integral-length theory* *2. Accuracy in calculating displacement thickness, momentum thickness, and shape factor*	
11	Memahami dan mampu menjelaskan tentang momentum integral-relation, analisis integral pada aliran laminar dan turbulen	Momentum integral-relation, analisis integral pada aliran laminar dan turbulen	Paparan Contoh perhitungan Diskusi	3 × 50’	Tugas kuliah	1.Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang momentum integral-relation 2.Ketepatan dalam melakukan perhitungan momentum integral-relation	

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	Able to understand and explain about momentum integral-relation, integral analysis on laminar and turbulent flow	*Momentum integral-relation, integral analysis on laminar and turbulent flow*	*Presentation* *Calculation example* *Discussion*		*Assignments*	*1.Accuracy and depth in providing a definition/description/explanation of momentum-integral relation* *2.Accuracy in calculating momentum-integral relation*	

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12	Mahasiswa mampu menjelaskan efek turbulensi pada mean flow *Able to explain the effect of turbulence on mean flow*	Efek turbulensi pada mean flow *effect of turbulence on the mean flow*	Paparan Contoh perhitungan Diskusi *Presentation* *Calculation example* *Discussion*	3 × 50’	Tugas kuliah *Assignments*	Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang efek turbulensi pada mean flow *Accuracy and depth in providing a definition/explanation/explanation on the effect of turbulence on the mean flow*	
13	Mahasiswa dapat mampu memahami dan menerapkan Eddy-viscosity models dan Non-linear eddy-viscosity models	Eddy-viscosity models dan Non-linear eddy-viscosity models	Paparan Contoh perhitungan Diskusi	3 × 50’	Tugas kuliah	Ketepatan dan kedalaman dalam menerapkan Eddy-viscosity models dan Non-linear eddy-viscosity models	

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	Able to understand and apply Eddy-viscosity models and Non-linear eddy-viscosity models	*Eddy-viscosity models and Non-linear eddy-viscosity models*	*Presentation* *Calculation example* *Discussion*		*Assignments*	*Accuracy and depth in applying Eddy-viscosity models and Non-linear eddy-viscosity models*	
14	1. Memahami dan mampu menjelaskan tentang konsep efek turbulensi dan model Eddy-viscosity linear dan non-liniear serta dapat melakukan analisis integral dan momentum integral-relation 2. Mahasiswa dapat mampu memahami dan menerapkan Reynolds-stress transport models (second-order closure)	Semua materi minggu 10-13	Paparan Contoh perhitungan Diskusi	3 × 50’	Tugas kuliah	1. Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang konsep efek turbulensi dan model Eddy-viscosity linear dan non-liniear 2. Ketepatan dalam melakukan analisis integral dan perhitungan momentum integral-relation	
	1. Able to understand and explain the concept of turbulence effects and linear and non-linear Eddy-viscosity models and can perform integral and momentum-integral-relation analyzes *2. Students can be able to understand and apply Reynolds-stress transport models (second-order closure)*	*All materials in 10th – 13th week*	*Presentation* *Calculation example* *Discussion*		*Assignments*	*1. Accuracy and depth in providing definition/explanation/explanation on the concept of turbulence effects and linear and non-linear Eddy-viscosity models* *2. Accuracy in performing integral analysis and momentum-integral-relation calculations*	

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15	Memahami dan mampu menjelaskan tentang kosep Persamaan Orr-Sommerfeld, stabilitas inviscid – persamaan Rayleigh, instabilitas viscous, instabilitas aliran tertentu. *Able to understand and explain the concept of the Orr-Sommerfeld Equation, inviscid stability – Rayleigh equation, viscous instability, certain flow instability.*	Reynolds-stress transport models (second-order closure) *Reynolds-stress transport models (second-order closure)*	Presentasi di depan kelas *Presentation In front of class*	3 × 50'	Tugas kuliah *Assignments*	Ketepatan dan kedalaman dalam memberikan definisi/ uraian/ penjelasan tentang Persamaan Orr-Sommerfeld, stabilitas inviscid – persamaan Rayleigh, instabilitas viscous, instabilitas aliran tertentu *Accuracy and depth in providing definitions/explanations/explanations on the Orr-Sommerfeld Equation, inviscid stability – Rayleigh equation, viscous instability, particular flow instability*	
16	Evaluasi Akhir Semester *Final Semester Evaluation*						

PUSTAKA/*REFERENCES*:

1. White, FM, 1991, Viscous fluid flow, McGraw-Hill
2. Schlichting, H. and Gersten, K., 1999, Boundary layer theory, 8 th English Edition, Springer-Verlag
3. Pope, SB, 2000, Turbulent flows, Cambridge University Press
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5. White, FM, 2002, Fluid mechanics, 5 th (International) Edition, McGraw-Hill