

O'Neill, *Semi-Riemannian Geometry*

365일 스터디 계획표

2026년 9월 14일–2027년 9월 13일

운영 기준

- 이미 공부한 Chapter 1의 Section 1.10까지는 제외하고 Section 1.11부터 시작한다.
- 전체 기간은 2026년 9월 14일부터 2027년 9월 13일까지 365일이다.
- 중간고사와 기말고사 기간 네 주를 제외하여 총 48개 학습 주차로 구성한다.
- 시험 휴식 주간은 2026년 10월 19일–25일, 12월 14일–20일, 2027년 4월 19일–25일, 6월 14일–20일로 가정한다.
- 쪽수는 첨부된 1983년 Academic Press 판본의 인쇄 쪽수를 따른다.

학습 주차	날짜	학습 범위	Key Topics
1	2026. 9. 14.–9. 20.	1.11–1.12 (pp. 24–33) Some Special Manifolds; Integral Curves	Examples of special manifolds; existence and uniqueness of integral curves; Chapter 1 exercises and review of earlier sections
2	9. 21.–9. 27.	2.1–2.4 (pp. 34–38) Basic Algebra; Tensor Fields; Interpretations; Tensors at a Point	Multilinear algebra; definition and interpretation of tensor fields; tensors at a point
3	9. 28.–10. 4.	2.5–2.8 (pp. 39–45) Tensor Components; Contraction; Covariant Tensors; Tensor Derivations	Tensor components; contraction; covariant tensors; tensor derivations
4	10. 5.–10. 11.	2.9–2.10 (pp. 46–57) Symmetric Bilinear Forms; Scalar Products	Symmetric bilinear forms; index and signature; scalar products; Chapter 2 exercises
5	10. 12.–10. 18.	3.1–3.2 (pp. 58–64) Isometries; The Levi-Civita Connection	Isometries; existence and uniqueness of the Levi-Civita connection; the Koszul formula
–	10. 19.–10. 25.	Midterm examination break — No study meeting	

다음 쪽에 계속

학습 주차	날짜	학습 범위	Key Topics
6	10. 26.–11. 1.	3.3–3.5 (pp. 65–73) Parallel Translation; Geodesics; The Exponential Map	Parallel translation; the geodesic equation; the exponential map and normal neighborhoods
7	11. 2.–11. 8.	3.6–3.7 (pp. 74–79) Curvature; Sectional Curvature	Definition and symmetries of the curvature tensor; sign conventions; sectional curvature
8	11. 9.–11. 15.	3.8–3.11 (pp. 80–86) Semi-Riemannian Surfaces; Type-Changing and Metric Contraction; Frame Fields; Some Differential Operators	Semi-Riemannian surfaces; type-changing and metric contraction; frame fields; gradient, divergence, and the Laplacian
9	11. 16.–11. 22.	3.12–3.15 (pp. 87–96) Ricci and Scalar Curvature; Product Manifolds; Local Isometries; Levels of Structure	Ricci and scalar curvature; product manifolds; local isometries; levels of geometric structure; Chapter 3 exercises
10	11. 23.–11. 29.	4.1–4.4 (pp. 97–105) Tangents and Normals; The Induced Connection; Geodesics in Submanifolds; Totally Geodesic Submanifolds	Tangent and normal spaces; the induced connection; the second fundamental form; geodesics in submanifolds
11	11. 30.–12. 6.	4.5–4.8 (pp. 106–117) Semi-Riemannian Hypersurfaces; Hyperquadrics; The Codazzi Equation; Totally Umbilic Hypersurfaces	Hypersurfaces; the shape operator; hyperquadrics; the Codazzi equation; totally umbilic hypersurfaces
12	12. 7.–12. 13.	4.9–4.12 (pp. 118–125) The Normal Connection; A Congruence Theorem; Isometric Immersions; Two-Parameter Maps	The normal connection; the congruence theorem; isometric immersions; two-parameter maps; Chapter 4 exercises
–	12. 14.–12. 20.	Final examination break — No study meeting	
13	2026. 12. 21.–12. 27.	5.1–5.2 (pp. 126–130) The Gauss Lemma; Convex Open Sets	The Gauss lemma; normal coordinates; convex open sets
14	2026. 12. 28.–2027. 1. 3.	5.3–5.5 (pp. 131–139) Arc Length; Riemannian Distance; Riemannian Completeness	Arc length; Riemannian distance; completeness and Hopf–Rinow-type consequences
15	1. 4.–1. 10.	5.6–5.8 (pp. 140–148) Lorentz Causal Character; Timecones; Local Lorentz Geometry	Timelike, spacelike, and null vectors; timecones; local Lorentz geometry
16	1. 11.–1. 17.	5.9–5.11 (pp. 149–157) Geodesics in Hyperquadrics; Geodesics in Surfaces; Completeness and Extendibility	Geodesics in model spaces and surfaces; completeness and extendibility; Chapter 5 exercises
17	1. 18.–1. 24.	6.1–6.5 (pp. 158–170) Newtonian Space and Time–Particles Observed	Structures of Newtonian and Minkowski spacetime; observers and particles
18	1. 25.–1. 31.	6.6–6.10 (pp. 171–184) Some Relativistic Effects–An Accelerating Observer	Relativistic effects; Lorentz contraction; energy-momentum; collisions; accelerating observers; Chapter 6 exercises
19	2. 1.–2. 7.	Appendix A and 7.1–7.3 (pp. 441–446, 185–190)	Fundamental groups and covering manifolds; deck transformations; orbit manifolds; orientability
20	2. 8.–2. 14.	7.4–7.9 (pp. 191–203) Semi-Riemannian Coverings–Matched Coverings	Semi-Riemannian coverings; time-orientability; volume elements; vector bundles; local isometries

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21	2. 15.–2. 21.	7.10–7.13 (pp. 204–214) Warped Products–Semi-Riemannian Submersions	Warped products and their geodesics and curvature; semi-Riemannian submersions; Chapter 7 exercises
22	2. 22.–2. 28.	8.1–8.3 (pp. 215–220) Jacobi Fields; Tidal Forces; Locally Symmetric Manifolds	Jacobi fields and geodesic variations; tidal forces; locally symmetric manifolds
23	3. 1.–3. 7.	8.4–8.7 (pp. 221–232) Isometries of Normal Neighborhoods–Transvections	Isometries of normal neighborhoods; symmetric spaces; simply connected space forms; transvections
24	3. 8.–3. 14.	Appendix B and 9.1–9.3 (pp. 447–452, 233–241)	Foundations of Lie groups and Lie algebras; semiorthogonal groups; isometry groups; time- and space-orientability
25	3. 15.–3. 21.	9.4–9.6 (pp. 242–251) Linear Algebra; Space Forms; Killing Vector Fields	Relevant linear algebra; isometries of space forms; Killing vector fields
26	3. 22.–3. 28.	9.7–9.9 (pp. 252–262) The Lie Algebra $\mathfrak{i}(M)$; $I(M)$ as Lie Group; Homogeneous Spaces	The Lie algebra of the isometry group; the Lie group structure of $I(M)$; homogeneous spaces; Chapter 9 exercises
27	3. 29.–4. 4.	10.1–10.3 (pp. 263–269) First Variation; Second Variation; The Index Form	First and second variations of length and energy; the index form
28	4. 5.–4. 11.	10.4–10.6 (pp. 270–279) Conjugate Points; Local Minima and Maxima; Some Global Consequences	Conjugate points; local extremal properties of geodesics; global consequences
29	4. 12.–4. 18.	10.7–10.9 (pp. 280–287) The Endmanifold Case; Focal Points; Applications	Variations with endpoint submanifolds; focal points; applications of the index form
–	4. 19.–4. 25.	Midterm examination break — No study meeting	
30	4. 26.–5. 2.	10.10–10.12 (pp. 288–299) Variation of E ; Focal Points along Null Geodesics; A Causality Theorem	Variation of energy; focal points along null geodesics; a causality theorem; Chapter 10 exercises
31	5. 3.–5. 9.	11.1–11.2 (pp. 300–305) More about Lie Groups; Bi-Invariant Metrics	Further properties of Lie groups; bi-invariant metrics and their curvature
32	5. 10.–5. 16.	11.3–11.4 (pp. 306–314) Coset Manifolds; Reductive Homogeneous Spaces	Coset manifolds; reductive homogeneous spaces; invariant connections
33	5. 17.–5. 23.	11.5–11.6 (pp. 315–320) Symmetric Spaces; Riemannian Symmetric Spaces	The structure of symmetric spaces; Riemannian symmetric spaces
34	5. 24.–5. 30.	11.7–11.8 (pp. 321–331) Duality; Some Complex Geometry	Duality of symmetric spaces; foundations of complex geometry; Chapter 11 exercises
35	5. 31.–6. 6.	Appendix C and 12.1–12.2 (pp. 453–455, 332–336)	Newtonian gravitation; geometric foundations of general relativity; the Einstein equation
36	6. 7.–6. 13.	12.3–12.4 (pp. 337–344) Perfect Fluids; Robertson–Walker Spacetimes	The energy-momentum tensor of a perfect fluid; Robertson–Walker metrics
–	6. 14.–6. 20.	Final examination break — No study meeting	

학습 주차	날짜	학습 범위	Key Topics
37	6. 21.–6. 27.	12.5–12.7 (pp. 345–352) The Robertson–Walker Flow; Robertson–Walker Cosmology; Friedmann Models	The Robertson–Walker flow and cosmology; the Friedmann equations; expanding-universe models
38	6. 28.–7. 4.	12.8–12.10 (pp. 353–363) Geodesics and Redshift; Observer Fields; Static Spacetimes	Geodesics and redshift; observer fields; static spacetimes; Chapter 12 exercises
39	7. 5.–7. 11.	13.1–13.2 (pp. 364–370) Building the Model; Geometry of N and B	Construction of the Schwarzschild model; geometry of N and B
40	7. 12.–7. 18.	13.3–13.5 (pp. 371–377) Schwarzschild Observers; Schwarzschild Geodesics; Free Fall Orbits	Schwarzschild observers; Schwarzschild geodesics; free-fall orbits
41	7. 19.–7. 25.	13.6–13.7 (pp. 378–383) Perihelion Advance; Lightlike Orbits	Perihelion advance; lightlike orbits; gravitational deflection of light
42	7. 26.–8. 1.	13.8–13.10 (pp. 384–391) Stellar Collapse; The Kruskal Plane; Kruskal Spacetime	Stellar collapse; the Kruskal plane; maximal analytic extension to Kruskal spacetime
43	8. 2.–8. 8.	13.11–13.12 (pp. 392–401) Black Holes; Kruskal Geodesics	The black-hole region; the event horizon; Kruskal geodesics; Chapter 13 exercises
44	8. 9.–8. 15.	14.1–14.2 (pp. 402–406) Causality Relations; Quasi-Limits	Chronological and causal relations; quasi-limits of sequences of curves
45	8. 16.–8. 22.	14.3–14.5 (pp. 407–414) Causality Conditions; Time Separation; Achronal Sets	The hierarchy of causality conditions; the time-separation function; achronal sets
46	8. 23.–8. 29.	14.6–14.8 (pp. 415–424) Cauchy Hypersurfaces; Warped Products; Cauchy Developments	Cauchy hypersurfaces; global hyperbolicity; warped products; Cauchy developments
47	8. 30.–9. 5.	14.9–14.10 (pp. 425–430) Spacelike Hypersurfaces; Cauchy Horizons	Geometry of spacelike hypersurfaces; Cauchy horizons
48	9. 6.–9. 13.	14.11–14.12 (pp. 431–440) Hawking’s Singularity Theorem; Penrose’s Singularity Theorem	Hypotheses and proof structures of the Hawking and Penrose singularity theorems; a dependency map for the whole book