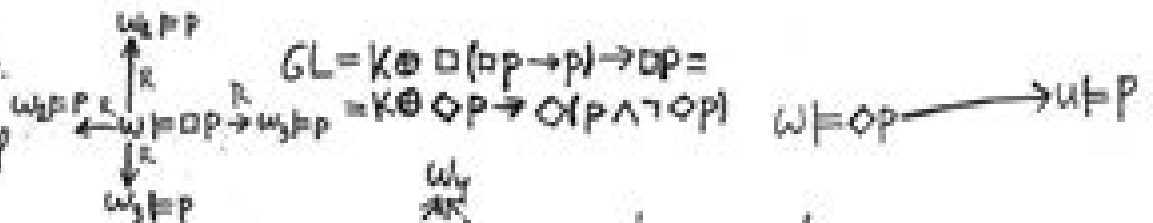


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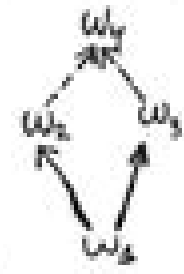
$$M, x \models \Box \varphi \iff \exists y \in R(x) M, y \models \varphi$$



$$K \vdash \Box(\varphi \vee \psi) \iff \Box\varphi \vee \Box\psi$$

**Theorem**  $S4 = \text{Log}(P)$  where  $P$  is the class of all preorders

**Sergokell**



**Lemma** Let  $M$  be a Kripke model and  $\Gamma$  a set of formulas closed under subformulas, then  $M, x \models \varphi \iff \bigwedge_{\psi \in \Gamma} M, x \models \psi$ , where  $\varphi \in \Gamma$ .

$$K4 = K \oplus \Box\Box p \rightarrow \Box p$$

# Incomplete and Utter

Hilbert-Bernays-Löb condition

- $\Box A \vdash A \Rightarrow \Box A \vdash \Box A$  ( $\Box A$ )
- $\Box A \vdash \Box(A \rightarrow B) \rightarrow (\Box A) \rightarrow \Box B$
- $\Box A \vdash \Box(\Box A) \rightarrow \Box(\Box A)$

$$\frac{\Box \Gamma \rightarrow \Gamma \quad \Box \varphi \rightarrow \Box \varphi}{\Gamma \rightarrow \Box \Gamma} \quad \frac{\Gamma \rightarrow \Box \Gamma}{\Box \Gamma \rightarrow \Box \Gamma}$$

# Introduction to

# Modal Logic

Let  $X = \langle X, \tau \rangle$  be a topological space and  $A \subseteq X$ . An interior of  $A$  is the set

$$I(A) = \bigcup \{ B \in \tau \mid B \subseteq A \}$$

Topology rules:

$$I(I(A)) = I(A)$$

$$A \subseteq B \Rightarrow I(A) \subseteq I(B)$$

$$I(A \cap B) = I(A) \cap I(B)$$

$$\Box \top \leftrightarrow \Box \Box \top \leftrightarrow \top$$

$$\Box A \vdash \perp \iff \Box A \vdash \Box \perp$$

Danya Rogozin

$$M, x \models \Box \perp \iff R(x) = \emptyset$$

- $f: W_1 \rightarrow W_2$  is a p-morphism:
- $a R_1 b \Rightarrow f(a) R_2 f(b)$
  - $f(a) R_2 c \Rightarrow \exists b \in W_1$  s.t.  $f(b) = c \ \& \ a R_1 b$

$$S4 \vdash \Box \Box p \leftrightarrow \Box p$$

$$M, x \models \Box^n \varphi \iff \exists y \in R^n(x) M, y \models \varphi$$

There is a possibility that never that never goes out.

# Modal Logic An Introduction

**Edward John Lemmon, Dana S. Scott**

## **Modal Logic An Introduction:**

Modal Logic Nino B. Cocchiarella, Max A. Freund, 2008-08-04 In this text a variety of modal logics at the sentential first order and second order levels are developed with clarity precision and philosophical insight All of the S1 S5 modal logics of Lewis and Langford among others are constructed A matrix or many valued semantics for sentential modal logic is formalized and an important result that no finite matrix can characterize any of the standard modal logics is proven Exercises some of which show independence results help to develop logical skills A separate sentential modal logic of logical necessity in logical atomism is also constructed and shown to be complete and decidable On the first order level of the logic of logical necessity the modal thesis of anti essentialism is valid and every de re sentence is provably equivalent to a de dicto sentence An elegant extension of the standard sentential modal logics into several first order modal logics is developed Both a first order modal logic for possibilism containing actualism as a proper part as well as a separate modal logic for actualism alone are constructed for a variety of modal systems Exercises on this level show the connections between modal laws and quantifier logic regarding generalization into or out of modal contexts and the conditions required for the necessity of identity and non identity Two types of second order modal logics one possibilist and the other actualist are developed based on a distinction between existence entailing concepts and concepts in general The result is a deeper second order analysis of possibilism and actualism as ontological frameworks Exercises regarding second order predicate quantifiers clarify the distinction between existence entailing concepts and concepts in general Modal Logic is ideally suited as a core text for graduate and undergraduate courses in modal logic and as supplementary reading in courses on mathematical logic formal ontology and artificial intelligence

**Modal Logic** Brian F. Chellas, 1980-02-29 A textbook on modal logic intended for readers already acquainted with the elements of formal logic containing nearly 500 exercises Brian F Chellas provides a systematic introduction to the principal ideas and results in contemporary treatments of modality including theorems on completeness and decidability Illustrative chapters focus on deontic logic and conditionality Modality is a rapidly expanding branch of logic and familiarity with the subject is now regarded as a necessary part of every philosopher s technical equipment Chellas here offers an up to date and reliable guide essential for the student

A New Introduction to Modal Logic M.J. Cresswell, G.E. Hughes, 2012-08-06 This long awaited book replaces Hughes and Cresswell s two classic studies of modal logic An Introduction to Modal Logic and A Companion to Modal Logic A New Introduction to Modal Logic is an entirely new work completely re written by the authors They have incorporated all the new developments that have taken place since 1968 in both modal propositional logic and modal predicate logic without sacrificing the clarity of exposition and approachability that were essential features of their earlier works The book takes readers from the most basic systems of modal propositional logic right up to systems of modal predicate with identity It covers both technical developments such as completeness and incompleteness and finite and infinite models and their philosophical applications especially in the area of modal predicate

logic     Introductory Modal Logic Kenneth Konyndyk,1986 Modal logic developed as an extension of classical propositional logic and first order quantification theory integrates the notions of possibility and necessity and necessary implication Arguments whose understanding depends on some fundamental knowledge of modal logic have always been important in philosophy of religion metaphysics and epistemology Moreover modal logic has become increasingly important with the use of the concept of possible worlds in these areas Introductory Modal Logic fills the need for a basic text on modal logic accessible to students of elementary symbolic logic Kenneth Konyndyk presents a natural deduction treatment of propositional modal logic and quantified modal logic historical information about its development and discussions of the philosophical issues raised by modal logic Characterized by clear and concrete explanations appropriate examples and varied and challenging exercises Introductory Modal Logic makes both modal logic and the possible worlds metaphysics readily available to the introductory level student     **Short Introduction to Modal Logic** Grigori Mints,1992-06-01 Modal Logic can be characterized as the logic of necessity and possibility of must be and may be A Short Introduction to Modal Logic presents both semantic and syntactic features of the subject and illustrates them by detailed analyses of the three best known modal systems S5 S4 and T The book concentrates on the logical aspects of the subject and provides philosophical motivations to show the point of the formal work The coverage is self contained including a summary of the necessary aspects of classical logic which it presupposes A set of exercises is included in the final chapter     Short Introduction to Modal Logic Grigori Mints,1992-06-01 Modal Logic can be characterized as the logic of necessity and possibility of must be and may be A Short Introduction to Modal Logic presents both semantic and syntactic features of the subject and illustrates them by detailed analyses of the three best known modal systems S5 S4 and T The book concentrates on the logical aspects of the subject and provides philosophical motivations to show the point of the formal work The coverage is self contained including a summary of the necessary aspects of classical logic which it presupposes A set of exercises is included in the final chapter     Official Summary of Security Transactions and Holdings Reported to the Securities and Exchange Commission Under the Securities Exchange Act of 1934 and the Public Utility Holding Company Act of 1935 ,1996     **An introduction to modal logic** George E. Hughes,1977     **An Introduction to Modal Logic** George Edward Hughes,Maxwell J. Cresswell,1977     **A new introduction to modal logic** ,1968     **An Introduction to Modal Logic** George Edward Hughes,M. J. Cresswell,1972     An Introduction to Modal Logic Richard E. Robinson,1983     **An Introduction to Classical and Modal Logics** Adam Bjorndahl,2024-08-31 Classical logic which studies the structural features of purported claims of fact and modal logic which studies relations of necessity and possibility are different but complementary areas of logical thought In this lively and accessible textbook Adam Bjorndahl provides a comprehensive and unified introduction to the two subjects treating them with the same level of rigour and detail and showing how they fit together The core material appears in the main text with hundreds of supplemental examples comments clarifications and connections presented

throughout in easy to read sidenotes giving the book a distinct conversational feel A detailed multi part appendix covers important background mathematical material that some students may lack such as induction or the concept of countable infinity A fully self contained learning resource this book will be ideal for a semester long upper level university course on either or both of the topics

**Modal Logic for Philosophers** James W. Garson,2013-11-25 This book on modal logic is especially designed for philosophy students It provides an accessible yet technically sound treatment of modal logic and its philosophical applications Every effort is made to simplify the presentation by using diagrams instead of more complex mathematical apparatus These and other innovations provide philosophers with easy access to a rich variety of topics in modal logic including a full coverage of quantified modal logic non rigid designators definite descriptions and the de re de dicto distinction Discussion of philosophical issues concerning the development of modal logic is woven into the text The book uses natural deduction systems which are widely regarded as the easiest to teach and use It also includes a diagram technique that extends the method of truth trees to modal logic This provides a foundation for a novel method for showing completeness that is easy to extend to quantifiers This second edition contains a new chapter on logics of conditionals an updated and expanded bibliography and is updated throughout

*Introductory Modal Logic* Kenneth J Jr Konyndyk,1986-05-31

**Handbook of Modal Logic** Patrick Blackburn,Johan F.A.K. van Benthem, Frank Wolter,2006-11-03 The Handbook of Modal Logic contains 20 articles which collectively introduce contemporary modal logic survey current research and indicate the way in which the field is developing The articles survey the field from a wide variety of perspectives the underling theory is explored in depth modern computational approaches are treated and six major applications areas of modal logic in Mathematics Computer Science Artificial Intelligence Linguistics Game Theory and Philosophy are surveyed The book contains both well written expository articles suitable for beginners approaching the subject for the first time and advanced articles which will help those already familiar with the field to deepen their expertise Please visit [http://people.uleth.ca/~woods/RedSeriesPromo\\_WP\\_PubSLPR.html](http://people.uleth.ca/~woods/RedSeriesPromo_WP_PubSLPR.html) Compact modal logic reference Computational approaches fully discussed Contemporary applications of modal logic covered in depth

[An Introduction to Modal Logic](#) Edward John Lemmon,Dana S. Scott,1977

**Many-Dimensional Modal Logics: Theory and Applications** A. Kurucz,F. Wolter,M. Zakharyashev,Dov M. Gabbay,2003-10-21 Modal logics originally conceived in philosophy have recently found many applications in computer science artificial intelligence the foundations of mathematics linguistics and other disciplines Celebrated for their good computational behaviour modal logics are used as effective formalisms for talking about time space knowledge beliefs actions obligations provability etc However the nice computational properties can drastically change if we combine some of these formalisms into a many dimensional system say to reason about knowledge bases developing in time or moving objects To study the computational behaviour of many dimensional modal logics is the main aim of this book On the one hand it is concerned with providing a solid mathematical foundation for this discipline while on the other hand it

shows that many seemingly different applied many dimensional systems e g multi agent systems description logics with epistemic temporal and dynamic operators spatio temporal logics etc fit in perfectly with this theoretical framework and so their computational behaviour can be analyzed using the developed machinery We start with concrete examples of applied one and many dimensional modal logics such as temporal epistemic dynamic description spatial logics and various combinations of these Then we develop a mathematical theory for handling a spectrum of abstract combinations of modal logics fusions and products of modal logics fragments of first order modal and temporal logics focusing on three major problems decidability axiomatizability and computational complexity Besides the standard methods of modal logic the technical toolkit includes the method of quasimodels mosaics tilings reductions to monadic second order logic algebraic logic techniques Finally we apply the developed machinery and obtained results to three case studies from the field of knowledge representation and reasoning temporal epistemic logics for reasoning about multi agent systems modalized description logics for dynamic ontologies and spatio temporal logics The genre of the book can be defined as a research monograph It brings the reader to the front line of current research in the field by showing both recent achievements and directions of future investigations in particular multiple open problems On the other hand well known results from modal and first order logic are formulated without proofs and supplied with references to accessible sources The intended audience of this book is logicians as well as those researchers who use logic in computer science and artificial intelligence More specific application areas are e g knowledge representation and reasoning in particular terminological temporal and spatial reasoning or reasoning about agents And we also believe that researchers from certain other disciplines say temporal and spatial databases or geographical information systems will benefit from this book as well Key Features Integrated approach to modern modal and temporal logics and their applications in artificial intelligence and computer science Written by internationally leading researchers in the field of pure and applied logic Combines mathematical theory of modal logic and applications in artificial intelligence and computer science Numerous open problems for further research Well illustrated with pictures and tables

**An Introduction to Modal Logic** George Edward Hughes, M. J. Cresswell, 1968      *Deontic Logic: Introductory and Systematic Readings* R. Hilpinen, 2012-12-06

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