Canadian Institute of Actuaries EDUCATION
Institut canadien des actuaires ÉDUCATION

CIA 2022 Education Syllabus

ACIA Capstone Exam and modules

October 2022

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ACIA Module Syllabus – Spring 2023

The ACIA modules are a core educational requirement toward ACIA designation. They are intended to bridge accredited university education or education obtained via other actuarial organizations with the work environment. They are administered online via the CIA learning management system.

The modules assume some knowledge of the topics acquired via a recognized university degree or through other Associate-level education. Outcomes that candidates are expected to achieve often cover multiple learning objectives, with an emphasis on communications in most tasks.

The modules contain recordings, short readings, and/or quizzes. Each module includes a case study that includes various deliverables such as emails, reports, memorandums, recorded presentations, or spreadsheets. These case studies apply theoretical topics covered in the candidate's university degree or other recognized Associate-level education to practical actuarial scenarios; the content should not be new to the candidate, but the application may be.

There is no formal prerequisite for the ACIA modules. Candidates in an accredited university will be expected to have completed some actuarial courses prior to completing the first ACIA module, likely in their second year of university. The second module should be completed when a candidate has nearly completed all courses relevant to the ACIA Capstone Exam. It is expected that these candidates undertake the second module in the last year of their university program. Candidates are responsible for ensuring they have the appropriate knowledge.

ACIA Module 1

A. Introduction and actuarial communications

Description: The first portion of the module introduces the profession and gives a general context to the candidate; it explains the history of the profession, describes the context of actuarial work and the different fields of practice. Communication in an actuarial setting is also discussed: audiences, technical and non-technical writing, and the impact of cultural diversity on communication. Finally, different channels of oral and written business communication (e.g., email, letter, memorandum, report, summary, presentation deck, messaging, and chat software) are introduced. Their purpose is explained, and the formatting rules for such communication are also exposed.

Content and learning objectives:

1. What it means to be an actuary in Canada
    a. Define the word "actuary" and what it means to be an actuary in Canada. Explain why actuaries are professionals.
    b. Describe historical events that have impacted the profession in Canada and worldwide.
    c. Describe today's areas of practice.
    d. Discuss the future of the actuarial profession.
2. Actuaries and the art of communication
    a. Understand the different audiences (e.g., peer to peer, within the firm, external clients, customers).
    b. Understand cultural diversity and its impact on communication.
    c. Develop written and oral communication intended for audiences within and outside the actuary's organization (i.e., match the audience with the purpose and medium of communication).
    d. Establish differences between technical and non-technical writing.
    e. Identify the appropriate use of different channels of written communication (e.g., email, letter, memorandum, report, summary).
    f. Understand the main characteristics and structure of these channels (i.e., the various parts of a letter, memorandum, report, summary).
    g. Compose emails, letters, memorandums, reports, and summaries.
    h. Write effective and concise written communication.
    i. Prepare meaningful visual media (e.g., charts, tables, infographics, videos) and visual aids (e.g., slides).

j. Identify key principles of effective public speaking and appropriate delivery techniques for in-person and virtual settings.

B. The actuarial environment

Description: The second portion of the module describes the actuarial environment: the financial systems, the external forces actuaries are facing, the risks stemming from changes in these external forces. Risk management, quantification, mitigation, and transfer are explained in detail. Emerging risks are also described. Finally, the candidate is exposed to the impact of regulations on the environment.

Content and learning objectives:

1. The context of actuarial work
    a. Understand how business works in various environments.
    b. Outline the context of actuarial work and its main processes.
    c. Define the main steps of risk management: identification, quantification, and mitigation.
    d. Explain the major sources of risk from (changing) external forces and their impact on our financial system.
2. Financial systems
    a. Describe financial systems within the national and global context.
    b. Describe the main participants in financial markets and explain their objectives and roles.
    c. Describe the major factors affecting the development of financial systems.
    d. Explain the main risks to the stability of national and global financial systems.
    e. Describe the operations, governance structure, legislative framework, capital, and risk management of Canadian financial institutions (e.g., insurance companies, banks).
    f. Describe the determinants of interest rates, price and wage inflation, GDP, and unemployment.
3. External forces
    a. Define external forces.
    b. Categorize the forces (e.g., cultural, demographic, economic, physical) and explain how they fit in the actuarial context.
    c. Explain how changes in external forces can lead to risk.
4. Risks and risk management
    a. Define and describe risk management in an actuarial context.
    b. Define risk types and classify them.
    c. Explain how risk can be transferred to others (e.g., hedging, insurance, reinsurance, specialized markets, retained versus ceded).
5. Emerging risks
    a. Explain how to identify new relevant risks.
    b. Describe the impact of climate change and cyber risk on actuarial risks.
    c. Explain blockchain and its impact on risk reduction.
6. Regulations
    a. Describe the regulatory context and the impact of regulations on actuarial work.
    b. Describe the international environment for actuarial work.

C. Actuarial work

Description: The third portion of the module builds on the actuarial environment and explains how actuaries work to provide sound solutions. An overview of actuarial work is provided, with a particular emphasis on the distinction between actuarial work and that of other financial experts. The actuarial control cycle is introduced, and each component of actuarial work is described. Decision-making and problem solving, and ethics and professionalism are also introduced.

Content and learning objectives:

1. Actuarial work
    a. Explain the difference between the work of an actuary and that of other financial experts.
2. The actuarial control cycle and the different steps of actuarial work
    a. Describe how actuarial solutions are developed to manage risk.
    b. Describe how actuarial solutions are designed and priced.
    c. Describe how models are selected and used in actuarial practice.
    d. Describe the processes used to determine assumptions.
    e. Describe the elements of the process of monitoring results.
3. Decision-making and problem solving
    a. Understand the dynamics of decision-making and outline its process.
    b. Evaluate the effect of firm structure and other stakeholders on decision-making.
    c. Define the impact of political, legislative, economic, societal, and technological trends on business strategy.
    d. Define, use, and apply the following: effective negotiation, decision-making skills, leadership, strategic insights, relationship management.
    e. Apply a decision-making process to case studies and problem solving.
4. Ethics and professionalism
    a. Describe ethics and professionalism and how they apply in everyday work.
    b. Explain the main principles of actuarial professionalism.
    c. Understand the importance of checking work and the need to consider peer review.
    d. Understand how to determine and apply professional standards and guidance appropriately, including when an assignment may be governed by professional standards of more than one actuarial organization.
    e. Understand the importance of being qualified to practice and the impacts of providing an opinion or doing work outside of your domain.
    f. Describe necessary standards of practice and their impact on actuarial work (e.g., data quality, assumptions).
    g. Understand the principles and importance of diversity, equity, and inclusion.

ACIA Module 2

D. Traditional actuarial solutions

Description: The fourth portion of the module complements university or other recognized education by reintroducing actuarial solutions to traditional problems. Fields of application of such traditional solutions could be pensions, life insurance, or general insurance.

Content and learning objectives:

1. Complement of long-term actuarial mathematics
    a. Describe why and how models are used for pricing, reserving, and assessing profitability and sustainability of life insurance products or pension arrangements.
    b. Apply actuarial models and cash-flow techniques used in pricing, reserving, and assessing profitability of contracts for contingent payments with appropriate allowance for expenses of life insurance and pension fund applications.
    c. Describe typical and practical applications of traditional long-term solutions, building on solutions commonly considered in a university education.
    d. Compare and justify actuarial solutions relative to long-term applications in the context of life insurance and pension.
    e. Draw connections between simple solutions part of a university education and advanced actuarial problems relative to long-term applications.
2. Complement of short-term actuarial mathematics
    a. Describe why and how models are used for pricing, reserving, and assessing profitability of short-term insurance products.
    b. Apply actuarial models and projected cash-flow techniques in pricing, reserving, and assessing profitability of contracts for contingent payments, with appropriate allowance for expenses of short-term insurance.
    c. Describe typical and practical applications of traditional short-term solutions, building on solutions already considered in university education.
    d. Compare and justify actuarial solutions relative to short-term applications.
    e. Draw connections between simple solutions part of a university education and advanced actuarial problems relative to short-term applications.
3. Communication of results and uncertainties
    a. Recognize appropriate model outputs to communicate the key elements of an actuarial solution and uncertainties, tailored to the intended audience.

E. Advanced actuarial models and predictive analytics applications

Description: This final portion of the module introduces predictive modelling to actuarial problems, building on the predictive analytics models taught at Canadian universities or through other recognized actuarial education to prepare candidates for the workplace. Examples will be applicable to all practice areas.

Content and learning objectives:

1. Notions in predictive analytics
    a. Identify the problem to be solved using predictive analytics techniques.
    b. Understand the business objectives, statistical objectives, and constraints of a problem, including implementation limitations and challenges.
    c. Explain how to create models that fit a business problem and that can be validated, monitored, and updated.
    d. Identify common issues and pitfalls such as correlation and causation, impact of data biases, and overfitting models.

2. Data and systems
    a. Describe measures of data quality and understand the importance of appropriate data.
    b. Construct datasets and use appropriate tools for cleaning, restructuring, and transforming data to be suitable for solving real-world problems, including how to handle missing data.
    c. Describe various data structures, sources of data, and their characteristics, including extremely large datasets.
    d. Describe the possible aims of a data analysis (e.g., descriptive, inferential, predictive).
    e. Explain the ethical, legal, and regulatory issues involved in using personal data and others' work.
    f. Explain the main issues to be addressed by a data governance policy and its importance for an organization.
    g. Explain the risks associated with use of data (including algorithmic decision-making).
3. Model selection and validation
    a. Evaluate the appropriateness of a model and its assumptions for addressing the business problem.
    b. Understand the difference between a stochastic and a deterministic model and identify the advantages/disadvantages of each.
    c. Explain the purposes of scenario-based and proxy models.
    d. Understand the short- and long-run properties of a model, and how this may be relevant in deciding whether a model is suitable for a particular application.
    e. Apply parsimony to model selection, balancing model complexity and accuracy.
    f. Discuss the business processes and limitations relative to the implementation of a predictive model.
    g. Use test data to estimate and confirm model parameters.
    h. Use graphical and quantitative tools to validate and monitor the model.
    i. Plan and produce a model with clear documentation, enabling detailed checking and high-level scrutiny.
    j. Perform checks on the results of a model, including applying sensitivity of assumptions and/or scenario tests.
4. Communication of results and uncertainties
    a. Create appropriate data visualizations to communicate the key elements of a predictive modelling analysis, tailored to the intended audience.
    b. Explain the meaning and value of reproducible research and describe the elements required to ensure a data analysis is reproducible.

ACIA Capstone Exam Syllabus – Spring 2023

Preamble

The overarching goal of the ACIA Capstone Exam is to help candidates prepare for the actuarial profession and tasks related to entry-level actuarial positions. Candidates are expected to demonstrate integration of knowledge of actuarial concepts and communicate results with a few short assignments. The exam assumes knowledge acquired in a recognized university degree, as well as from the ACIA module, focusing on application and communication.

The ACIA Capstone Exam is administered as an open-book, six-hour exam, requiring analysis in the context of a problem and submission of written responses to specified tasks. The exam is split into two sections: a four-hour mandatory common section and a two-hour specialized section, long- or short-term, selected at exam registration.

Candidates will complete the exam through the learning management system, with secure online proctoring. The exam is open book and candidates are responsible for bringing their own reference material to the exam. Strict adherence to the exam rules and regulations, which will be communicated in advance, is mandatory.

General learning objectives

General learning objectives are shown below, with Bloom's taxonomy classification in parentheses.

1. Demonstrate a clear understanding of actuarial problems. (B5)
2. Apply mathematical, statistical, and financial models and methods to solve actuarial problems. (C3)
3. Produce efficient and readable computer codes to implement actuarial models in various platforms, such as R and Excel. (C6)
4. Perform an actuarial analysis to support decision-making in a given business environment. (C4)
5. Formulate and support recommendations based on actuarial analysis in a business context. (C6)
6. Write an effective communication (e.g., executive summary, email, presentation, excerpts from a report) on assumptions, methods, and results of actuarial analysis to an appropriate audience (e.g., peers, internal stakeholders, management). (C6)

Topics assessed on the exam

The exam is composed of two parts – Part 1 and Part 2a or 2b, as outlined below. Please refer to the "Appendix to the CIA Capstone Exam Syllabus" and to the "ACIA Module Syllabus" for more details on the background knowledge.

Exam part	Duration	Topics/background knowledge from accredited university degree	Topics/background knowledge from ACIA module
1. Common	4 hours	A3.9 to A3.13 A4.1 to A4.4 A4.7 to A4.14 A5, except A5.3 and A5.4	A, B, C
2a. Specialized: Long-term	2 hours	A3.9 to A3.13 A4.1 to A4.6	A, B, C, D1, E
2b. Specialized: Short-term	2 hours	A4.7 to A4.15 A5	A, B, C, D2, E

References relative to the topics can also be found in the appendix.

Considerations on exam/performance assessment by the CIA

Performance of a candidate's answers will be evaluated on the following principles:

1. The overall quality of the answers' technical components:
    a. The accuracy of the steps leading to the results (e.g., method, code, answers, formulas used in worksheets).
    b. The relevance and coherence of the analyses performed with code and worksheets provided.
2. The overall quality of the communication:
    a. The ability to effectively communicate a complex analysis and solution to the targeted audience for the appropriate purpose.
    b. The ability to appropriately address the problem or the given mandate.

Candidates are highly encouraged to document and comment their computer code to help demonstrate their ability to translate an abstract actuarial problem into a computer program. Performance will also be assessed on the nature of the assignments.

Bloom's Taxonomy

The syllabuses set out the depth of knowledge and application required, using the revised Bloom's taxonomy of education objectives. For comparison purposes, the development of the IAA education syllabus is also based on the revised Bloom's taxonomy. This model reflects two dimensions: knowledge and cognitive process. The framework is widely used and respected by educators worldwide.

Revised Bloom's Taxonomy (RBT)

Cognitive Process Dimension

Verbs → / Objects ↓	1. **REMEMBER** Recognize, Recall	2. **UNDERSTAND** Interpret, Exemplify, Classify, Summarize, Infer, Compare, Explain	3. **APPLY** Execute, Implement	4. **ANALYZE** Differentiate, Organize, Attribute	5. **EVALUATE** Check, Critique	6. **CREATE** Generate, Plan, Produce
A. Factual Knowledge	A1	A2	A3	A4	A5	A6
B. Conceptual Knowledge	B1	B2	B3	B4	B5	B6
C. Procedural Knowledge	C1	C2	C3	C4	C5	C6
D. Metacognitive Knowledge	D1	D2	D3	D4	D5	D6

Appendix to the ACIA Capstone Exam Syllabus – Spring 2023

A university-accredited degree and successful completion of the ACIA module is required background knowledge to the Capstone Exam. This appendix outlines the background knowledge covered in an accredited university degree. Please refer to the "ACIA Module Syllabus" for related topics and learning objectives.

A1. Probability

A1.1 Probability

a. Define set functions, sample space, and events. Define probability as a set function on a collection of events and state the basic axioms of probability.

b. Calculate probabilities of mutually exclusive events.

c. Calculate probabilities using addition and multiplication rules.

d. Define independence and calculate probability of independent events.

e. Calculate probabilities using combinatorics, such as combinations and permutations.

f. Define and calculate conditional probabilities.

g. State Bayes's theorem and use it to calculate conditional probabilities.

A1.2 Univariate random variables

a. Explain and apply the concepts of random variables, probability and probability density functions, and cumulative distribution functions.

b. Calculate conditional probabilities.

c. Explain and calculate expected value, mode, median, percentile, and higher moments.

d. Explain and calculate variance, standard deviation, and coefficient of variation.

e. Define probability-generating functions and moment-generating functions and use them to calculate probabilities and moments.

f. Determine the sum of independent random variables (Poisson and normal).

A1.3 Multivariate random variables

a. Explain and perform calculations concerning joint probability and probability density functions and cumulative distribution functions.

b. Determine conditional and marginal probability and probability density functions and cumulative distribution functions.

c. Calculate moments for joint, conditional, and marginal random variables.

d. Explain and apply joint moment-generating functions.

e. Calculate variance and standard deviation for conditional and marginal probability distributions.

f. Calculate joint moments, such as the covariance and the correlation coefficient.

g. Determine the distribution of a transformation of jointly distributed random variables.

h. Determine the distribution of order statistics from a set of independent random variables.

i. Calculate probabilities and moments for linear combinations of independent random variables.

j. State and apply the central limit theorem.

A2. Financial mathematics

A2.1 Time value of money

a. Define and recognize the definitions of the following terms: interest rate; simple interest; compound interest; accumulation function; future value; current value, present value, and net present value; discount factor; discount rate; convertible m-thly; nominal rate; effective rate; inflation and real rate of interest; force of interest; and equation of value.

b. Given any three of interest rate, period, present value, and future value, calculate the remaining item based on simple or compound interest.

c. Solve time value of money equations involving variable force of interest.

d. Given any one of the effective interest rate, the nominal interest rate convertible m-thly, the effective discount rate, the nominal discount rate convertible m-thly, or the force of interest, calculate all of the other items.

e. Write the equation of value given a set of cash flows and an interest rate.

A2.2 Annuities with payments that are not contingent

a. Define the following terms: annuity-immediate; annuity-due; perpetuity; payable m-thly or payable continuously; level-payment annuity; arithmetic increasing/decreasing annuity; geometric increasing/decreasing annuity; and term of annuity.

b. For each of the following types of annuity and cash flows, given sufficient information of immediate or due, present value, future value, current value, interest rate, payment amount, and term of annuity, the candidate should be able to calculate any remaining item: level annuity, finite term; and level perpetuity; and non-level annuities/cash flows: arithmetic progression, finite term; arithmetic progression, perpetuity; geometric progression, finite term; geometric progression, perpetuity; and other non-level annuities/cash flows.

A2.3 Loans

a. Define the following terms: principal, interest, term of loan, outstanding balance, final payment (drop payment, balloon payment), amortization, and sinking fund.

b. Given any four of term of loan, interest rate, payment amount, payment period, or principal, calculate the remaining item, including refinancing.

c. Calculate the outstanding balance at any point in time, the amount of interest and principal repayment in a given payment, including refinancing.

d. Given the quantities, except one, in a sinking-fund arrangement, calculate the missing quantity, including refinancing.

A2.4 Bonds

a. Define the following terms: price; redemption value; par value/face value; coupon, coupon rate; term of bond; yield rate; callable/non-callable; book value; and accumulation of discount, amortization of premium.

b. Given sufficient partial information about the following items, calculate any of the remaining items: price, book value, amortization of premium, accumulation of discount, redemption value, face value, yield rate, coupon, coupon rate, term of bond, point in time that a bond has a given book value, amortization of premium, or accumulation of discount.

A2.5 General cash flows and portfolios

a. Define the following terms: yield rate/rate of return; dollar-weighted rate of return/time-weighted rate of return; current value; duration (Macaulay, modified); convexity (Macaulay, modified); portfolio; spot rate; forward rate; yield curve; and stock price, stock dividend.

b. Calculate the portfolio yield rate, the dollar-weighted and time-weighted rate of return, the duration and convexity of a set of cash flows, and the Macaulay or modified durations.

c. Use duration and convexity to approximate the change in present value due to a change in interest rate using first-order linear approximation based on Macaulay or modified duration.

d. Calculate the price of a stock using the dividend discount model.

e. Explain how market data can be used to construct a yield curve.

f. Apply the term structure of interest rates to modelling various cash flows, including calculating the sensitivity of the value to changes in the term structure.

g. Describe the characteristics of the main investment assets and of the markets in such assets and explain the principal economic influences on investment market price levels and total returns.

h. Explain the principal economic influences on investment market price levels and total returns, and describe and explain the theoretical and historical relationships between the total returns and the components of total returns on the main asset classes and key economic variables.

A2.6 Immunization

a. Define and recognize the definitions of the following terms: cash-flow matching, immunization (including full immunization), and Redington immunization.

b. Construct an investment portfolio to fully immunize a set of liability cash flows, an investment portfolio to match present value and duration of a set of liability cash flows, and an investment portfolio to exactly match a set of liability cash flows.

c. Explain how asset/liability modelling can be used to develop an appropriate investment strategy; explain methods of quantifying the risk of investing in different classes and subclasses of investment.

d. Calculate the price of a stock using the dividend discount model.

e. Explain how market data can be used to construct a yield curve.

f. Apply the term structure of interest rates to modelling various cash flows, including calculating the sensitivity of the value to changes in the term structure.

g. Describe the characteristics of the main investment assets and of the markets in such assets and explain the principal economic influences on investment market price levels and total returns.

h. Explain the principal economic influences on investment market price levels and total returns; describe and explain the theoretical and historical relationships between the total returns and the components of total returns on the main asset classes and key economic variables.

A2.7 Interest rate swaps

a. Recognize and define the following terms: swap rate, swap term, or swap tenor; notional amount; market value of a swap; settlement dates; settlement period; counterparties; deferred swap; amortizing swap; accreting swap; and interest rate swap net payments.

b. Calculate the swap rate and the market value of an interest rate swap, deferred or otherwise, and with either constant or varying notional amount.

c. Explain how asset/liability modelling can be used to develop an appropriate investment strategy; explain methods of quantifying the risk of investing in different classes and subclasses of investment.

A2.8 Determinants of interest rates

a. Define and recognize the components of interest rates including the following: real risk-free rate, inflation rate, default risk premium, liquidity premium, and maturity risk premium.

b. Explain how the components of interest rates apply in various contexts, such as commercial loans, mortgages, credit cards, bonds, and government securities.

c. Explain the theories of why interest rates differ by term, including liquidity preference (opportunity cost), expectations, preferred habitat, and market segmentation.

d. Explain how interest rates differ from one country to another (e.g., U.S. vs. Canada).

A3. Business, economics, and finance

A3.1 Basic accounting and finance

a. Describe the basic principles of personal and corporate taxation and the taxation of investments held by institutions.

b. Explain why companies are required to produce annual reports and accounts.

c. Explain fundamental accounting concepts and terms and describe the main sources of accounting regulation.

d. Explain the purpose and interactions between a statement of financial performance, statement of financial position, and cash-flow statements.

e. Explain the value of reporting on environmental, social, and economic sustainability, and other alternatives to traditional financial reporting, and describe possible contents of such reports.

f. Explain the basic structure of company and group accounts.

g. Explain the purpose of the main components of company accounts and interpret them.

h. Construct simple statements of financial position and profit or loss.

i. Calculate and interpret financial and accounting ratios.

j. Explain the characteristics of various forms of equity capital from the point of view of the issuer and the investor.

k. Explain the characteristics of various forms of long-term debt capital from the point of view of the issuer and the investor.

l. Explain the characteristics of various forms of short- and medium-term financing from the point of view of the issuer and the investor.

m. Calculate weighted-average cost of capital.

n. Explain the main methods of capital budgeting.

o. Calculate a project's investment return.

A3.2 Microeconomics

a. Explain the concept of utility and how rational utility-maximizing agencies make consumption choices.

b. Explain the elasticity of supply and demand and the effects on a market of the different levels of elasticity.

c. Explain the interaction between supply and demand and the way in which equilibrium market prices are achieved.

d. Explain various pricing strategies that can be used by firms.

e. Explain the core economic concepts involved in choices made by businesses with respect to short- and long-run investment and production choices.

f. Explain competitive markets and how they operate.

g. Explain profitability in markets with imperfect competition.

A3.3 Macroeconomics

a. Explain basic macroeconomic measures (e.g., GDP) used to compare the economies of countries.

b. Describe the structure of public finances for an industrialized country.

c. Explain the effect of fiscal and monetary policy on the economy, including the effect on financial markets.

d. Explain the role of international trade, exchange rates, and the balance of payments in the economy.

e. Explain the effect of savings and consumption rates on the economy.

f. Explain the major factors affecting the level of interest rates, the rate of inflation, the exchange rate, the level of employment, and the rate of growth for an industrialized country.

g. Describe the function of money in the economy.

h. Explain how interest rates are determined.

i. Explain the relationship between money and interest rates.

j. Explain how macroeconomic policies affect businesses.

A3.4 Mean-variance portfolio theory

a. Estimate the risk and return of an asset, given appropriate inputs.

b. Calculate the risk and expected return of a portfolio of many risky assets, given the expected return, volatility, and correlation of returns of the individual assets.

c. Explain the assumptions of mean-variance theory and understand the importance of the mean/standard-deviation diagram and the resulting efficient market frontier.

d. Calculate the optimal portfolio, locate the capital market line, and describe the limitations of this approach.

e. Describe how portfolio risk can be reduced through diversification across multiple securities or across multiple asset classes.

A3.5 Asset pricing models

a. Explain the assumptions and properties of the capital asset pricing model (CAPM).

b. Calculate the required return on a particular asset, a portfolio, or a project using the CAPM.

c. Explain the assumptions of a factor model for security returns.

d. Identify the expected return, factors, factor betas, and firm-specific components of a security from its factor equation.

e. Calculate the required return on a particular asset, a portfolio, or a project using a single-factor and a multi-factor model.

A3.6 Market efficiency and behavioural finance

a. Understand the definition of efficient markets and distinguish between the strong, semi-strong, and weak versions of the efficient-market hypothesis (EMH).

b. Identify empirical evidence for or against each form of the EMH.

c. Identify empirical examples of market anomalies that show results contrary to the EMH.

d. Use behavioural finance to demonstrate why asset prices, especially in times of uncertainty and high volatility, may deviate from their fundamental values.

A3.7 Investment risk and project analysis

a. Define the following measures of investment risk: variance, semi-variance, value at risk (VaR) and tail value at risk (TVaR).

b. Explain the advantages and disadvantages of the risk measures listed above.

c. Calculate the risk measures listed above to compare investment opportunities.

d. Understand the following methods to conduct risk analysis: sensitivity analysis, break-even analysis, scenario analysis, and Monte Carlo simulation.

e. Use a decision tree to model future outcomes and analyze real options embedded in a project.

A3.8 Capital structure

a. Understand the two main forms of financing: equity issues and debt issues.

b. Describe the process by which a company raises capital, including venture capital, IPOs, additional issues, and private placement.

c. Calculate the effect from changes in capital structure on a company's overall value, equity beta, cost of debt, cost of equity, and weighted-average cost of capital, assuming the two Modigliani–Miller propositions hold.

d. Describe the effect of corporate tax and costs of financial distress, including the threat of bankruptcy, on the capital structure of a company.

e. Explain the role of agency costs and asymmetric information in affecting a company's pecking order of financing choices.

f. Describe different possible structures for a business entity and their advantages and disadvantages.

g. Explain the principles and objectives of investment management and analyze the investment needs of an institutional or individual investor.

h. Describe methods for the valuation of asset portfolios and explain their appropriateness in different situations.

A3.9 Introductory derivatives – forwards and futures

a. Distinguish between long and short positions for both assets (including short selling of stocks) and derivatives on assets.

b. Recognize the transaction costs affecting profit calculations for both assets and derivatives on assets (including commissions and bid-ask spread).

c. Recognize the definitions of the following terms relating to both forward contracts and prepaid forward contracts: forward contract, prepaid forward contracts, outright purchase, fully leveraged purchase, payoff of long and short forward, net profit of long and short forward.

d. Determine payoffs and profits for both long and short positions on forward contracts.

e. Calculate prices for both forward contracts and prepaid forward contracts on stocks with no dividends, continuous dividends, and discrete dividends.

f. Construct a synthetic forward from the underlying stock and a risk-free asset, and identify arbitrage opportunities when the synthetic forward price is different from the market forward price.

g. Recognize the definitions of the following terms: marking to market, margin balance, maintenance margin, and margin call.

h. Evaluate an investor's margin balance based on changes in asset values.

A3.10 General properties of options

a. Define and recognize the following terms: call and put options, expiration date, strike price, moneyness, and option style.

b. Calculate the payoff and profit on both long and short positions with respect to both call and put options.

c. Explain the cash-flow characteristics of exotic options: Asian (arithmetic and geometric), barrier, compound, gap, exchange, and lookback.

d. Calculate the payoffs on exotic options: lookback, chooser, shout, rainbow, and forward start.

e. Recognize that a long put can be used as an insurance strategy for a long stock position and a short call can be used as an insurance strategy for a short stock position.

f. Explain how the following option strategies can be used as tools to manage financial risk or speculate on price or volatility: option spreads (bull, bear, ratio), collar, straddle, strangle, and butterfly spread.

g. Evaluate the payoff and profit of the option strategies described above.

h. Apply put-call parity to European options on stocks with no dividends, continuous dividends, and discrete dividends.

i. Compare options with respect to term-to-maturity and strike price.

j. Identify factors affecting the early exercise of American options and the situations where the values of European and American options are the same.

A3.11 Binomial pricing models

a. Explain the concept of no arbitrage when comparing actual and synthetic calls or when comparing actual and synthetic puts.

b. Explain the concepts underlying the risk-neutral approach to valuing derivatives securities in the context of the binomial option pricing model.

c. Price options under a one-period binomial model on a stock with no dividends.

d. Extend the binomial model to multi-period settings for pricing European and American call and put options as well as the following option types: Asian, barrier, and gap.

e. Extend the binomial model to other underlying assets, including stock indices with continuous dividends, stocks with discrete dividends, currencies, and futures contracts.

A3.12 Black–Scholes option pricing model

a. Calculate log-normal-based probabilities and percentiles for stock prices.

b. Calculate log-normal-based means and variances of stock prices.

c. Calculate log-normal-based conditional expectations of stock prices given that options expire in the money.

d. Recognize the assumptions underlying the Black–Scholes model.

e. Use the Black–Scholes formula to value European calls and puts on stocks with no dividends, stock indices with continuous dividends, stocks with discrete dividends, currencies, and futures contracts.

f. Generalize the Black–Scholes formula to value gap calls, gap puts, and exchange options, chooser options, and forward-start options.

g. Estimate a stock's historical volatility from past stock-price data.

A3.13 Option Greeks and risk management

a. Compute and interpret option Greeks, including Delta, Gamma, Theta, Vega, Rho, and Psi.

b. Compute the elasticity, Sharpe ratio, and risk premium for both an individual option (call or put) and a portfolio consisting of both options of multiple types and the underlying stock.

c. Approximate option prices using Delta, Gamma, and Theta.

d. Perform delta hedging by calculating the quantities of option units, stock shares, and cash to hold, and whether those positions should be long or short.

e. Perform gamma hedging by calculating the quantities of option units (of various types) and stock shares to hold, and whether those positions should be long or short.

f. Explain how life insurers use derivatives to hedge long-term risks from the asset portfolio.

g. Explain how P&C insurers use derivatives to hedge short-term risks from the liability portfolio.

h. Explain how investment guarantees can be formed from equity-linked insurance and annuities.

i. Explain how options are employed in both pension funding and asset/liability management.

A4. Actuarial mathematics

A4.1 Long-term insurance coverages

a. Describe the long-term coverages in insurance (life, health, and general), annuities, and retirement benefits (e.g., pensions, retiree health care, etc.).

b. Describe the similarities and differences among the long-term coverages identified in a).

c. Describe the appropriate models to be used to calculate expected present values, premiums or contributions, and reserves for each long-term coverage.

A4.2 Survival models and their estimation

a. Explain and interpret survival models and transition between states.

b. Calculate and interpret standard functions including survival and mortality probabilities, force of mortality, and complete and curtate expectation of life.

c. Calculate non-parametric estimates of survival models using the Kaplan–Meier, Nelson–Aalen, Cox proportional-hazards, and Kernel density estimators' formulas for seriatim data and adaptations for grouped data.

d. Calculate, using both seriatim and grouped data, maximum likelihood estimates of transition probabilities assuming constant transition intensity during fixed age intervals.

e. Calculate the variances of and construct confidence intervals for the estimators in parts c) and d).

f. Calculate transition intensities exactly or estimate transition intensities using large sample approximations.

g. Describe and apply simple longevity models.

h. For models dealing with multiple lives and/or multiple states, explain the random variables associated with the model and calculate and interpret marginal and conditional probabilities.

i. Construct and interpret select and ultimate survival models, including computer applications.

j. Describe the behavior of Markov chain models, identify possible transitions between states, and calculate and interpret the probability of being in a particular state and transitioning between states.

k. Apply to calculations involving these models' appropriate approximation methods for fractional ages based on uniform distribution of deaths or constant force.

A4.3 Present value random variables

a. Calculate and interpret probabilities, means, percentiles, and higher moments.

b. Calculate and interpret the effect of changes in underlying assumptions such as mortality and interest.

c. Apply to calculations involving these random variables appropriate approximation methods such as uniform distribution of deaths, constant force, Woolhouse, and Euler.

A4.4 Long-term insurance premium calculation

a. Calculate and interpret probabilities, means, percentiles, and higher moments of random variables associated with these premiums, including loss-at-issue random variables.

b. Using any of the models in learning objective A4.3 c), calculate and interpret the effect of changes in policy design and underlying assumptions such as changes in mortality, benefits, expenses, interest, and dividends.

c. Perform the calculations in a) and b) for contracts associated with specified contingent cash flows, including annuities, universal life, and participating insurance.

d. Apply to calculations involving these premiums appropriate approximation methods such as uniform distribution of deaths, constant force, Woolhouse, and Euler.

A4.5 Long-term insurance reserves

a. Calculate and interpret the following reserve types: net premium, modified, gross premium, expense.

b. Calculate and interpret probabilities, means, variances, and percentiles of random variables associated with these reserves, including future-loss random variables.

c. Calculate and interpret common profit measures such as expected profit, actual profit, gain, gain by source and period, internal rate of return, profit margin, and break-even year.

d. Apply appropriate approximation methods such as uniform distribution of deaths, constant force, Woolhouse, and Euler.

A4.6 Pension plans and retirement benefits

a. Describe and compare defined benefit and defined contribution pension plans, including final salary and career average earning plans.

b. Describe retiree health-care plans.

c. Identify and interpret the common states and decrements for pension plans and the parametric and tabular models, including Markov chain models, associated with these decrements.

d. Given particular participant data, plan provisions, and valuation assumptions, apply the models mentioned in c) to defined benefit pension plans and calculate and interpret replacement ratios, accrued benefits, gain or loss, and their expected values with adjustments such as the early-retirement reduction factor.

e. Given particular participant data, plan provisions, and valuation assumptions, calculate and interpret the actuarial accrued liability and the normal cost for defined benefit plans under projected unit credit (PUC) and traditional unit credit (TUC) cost methods.

f. Calculate and interpret the effect of changes in underlying valuation assumptions such as mortality, discrete salary increases, other decrements, and interest on the quantities mentioned in d) and e).

g. Apply to calculations involving these plans and benefits appropriate approximation methods, such as uniform distribution of deaths, constant force, Woolhouse, and Euler.

A4.7 Severity models

a. Calculate the basic distributional quantities: moments, percentiles, generating functions.

b. Describe how changes in parameters affect the distribution.

c. Recognize classes of distributions, including extreme value distributions, suitable for modelling the distribution of severity of loss and their relationships.

d. Apply the following techniques for creating new families of distributions: multiplication by a constant, raising to a power, exponentiation, and mixing.

e. Identify the applications in which each distribution is used and the reasons why.

f. Apply the distribution to an application given the parameters.

g. Compare two distributions based on various characteristics of their tails, including moments, ratios of moments, limiting tail behavior, hazard rate function, and mean excess function.

A4.8 Frequency models

For the Poisson, mixed Poisson, binomial, negative binomial, geometric distribution, and mixtures thereof:

a. Describe how changes in parameters affect the distribution.

b. Calculate moments and generating functions.

c. Identify the applications for which each distribution is used and reasons why.

d. Apply the distribution to an application given the parameters.

e. Apply the zero-truncated or zero-modified distribution to an application given the parameters.

f. Recognize classes of distributions and their relationships.

A4.9 Aggregate models

a. Define collective and individual risk models and calculate their expectation and variance.

b. Use the normal distribution to approximate the aggregate distribution.

c. Use the recursive formula to calculate the values of the collective risk models with discrete distributions of severities.

d. Calculate the expected aggregate payments in the presence of an aggregate deductible.

e. Evaluate the effect of the coverage modifications on the expected aggregate payments.

f. Perform the exact calculation of aggregate loss distribution in case of the normal distribution of severities, exponential and gamma (Erlang) distribution of severities, and a compound model with negative binomial frequency and exponential distribution of severities.

A4.10 Coverage modifications

For frequency, severity, and aggregate models:

a. Evaluate the effect of coverage modifications, in particular, deductibles, limits, and co-insurance.

b. Calculate loss elimination ratios and increased limits factors.

c. Evaluate the effects of inflation on losses.

A4.11 Risk measures

a. Calculate value at risk (VaR) and tail value at risk (TVaR) and explain their use and limitations.

b. Explain the desirable properties of a risk measure and determine whether a given risk measure has these properties.

A4.12 Construction and selection of parametric models

a. Estimate the parameters for severity, frequency, and aggregate distributions using maximum likelihood estimation for:

   i. Complete, individual data;

   ii. Complete, grouped data; and

   iii. Truncated or censored data.

b. Estimate the variance of the estimators and construct confidence intervals.

c. Use the delta method to estimate the variance of the maximum likelihood estimator of a function of the parameter(s).

d. Estimate the parameters for severity, frequency, and aggregate distributions using Bayesian estimation.

e. Perform model selection using the following (including graphical procedures):

   i. Hypothesis tests, including chi-square goodness-of-fit and likelihood ratio test (LRT), and computer applications.

   ii. Score-based approaches, including Schwarz's Bayesian criterion (SBC)/Bayesian information criterion (BIC), and Akaike information criterion (AIC).

A4.13 Credibility

a. Apply limited fluctuation (classical) credibility, including criteria for both full and partial credibility.

b. Perform Bayesian analysis using both discrete and continuous models.

c. Apply Bühlmann and Bühlmann–Straub models and understand the relationship of these to the Bayesian model.

d. Apply conjugate priors in Bayesian analysis and, in particular, the Poisson-gamma model.

e. Apply empirical Bayesian methods in the non-parametric and semi-parametric cases.

f. Calculate Bayes estimate/Bayesian premium.

A4.14 Short-term insurance and reinsurance coverages

a. Describe different types of short-term insurance coverage, including homeowners, liability, health, disability, and dental.

b. Describe the types of policy limits and coverage modifications for short-term insurance.

c. Describe the operation of basic forms of proportional and excess of loss reinsurance.

d. Derive the distribution of claim amounts paid by the insurer and reinsurer under various forms of reinsurance.

A4.15 Pricing and reserving for short-term insurance coverages

a. Explain the role of rating factors and exposure.

b. Describe the different forms of experience rating.

c. Describe and apply techniques for estimating unpaid losses from a run-off triangle using the chain ladder, average cost per claim, and Bornhuetter–Ferguson methods.

d. Describe the underlying statistical models for the methods in c).

e. Calculate premiums using the pure premium and loss ratio methods.

A5. Predictive analytics

A5.1 Basics of statistical learning

Candidates will be able to do the following:

a. Explain the types of modelling problems and methods, including supervised versus unsupervised learning and regression versus classification.

b. Explain the common methods of assessing model accuracy.

c. Employ basic methods of exploratory data analysis, including data checking and validation.

A5.2 Generalized linear models

a. Describe and explain the components of, in particular, the exponential family of distributions and link functions.

b. Estimate parameters using least squares and maximum likelihood.

c. Interpret diagnostic tests of model fit and assumption checking using both graphical and quantitative methods.

d. Select an appropriate model, including distribution and link function, variable transformations and interactions, Pearson's chi-square statistic, t and F tests, likelihood ratio test, and AIC and BIC.

e. Interpret model results with emphasis on using the model to answer the underlying business question.

f. Calculate and interpret predicted values, confidence, and prediction intervals.

g. Understand how approaches may differ compared to using an ordinary least squares model, including lasso, ridge regression, and k-nearest neighbors (KNN).

h. Implement ordinary least squares regression in a coding language and understand model assumptions.

i. Understand the specifications of the GLM and the model assumptions.

j. Create new features appropriate for GLMs.

k. Interpret model coefficients, interaction terms, offsets, and weights.

l. Select and validate a GLM appropriately.

m. Explain the concepts of bias, variance, model complexity, and the bias-variance trade-off.

n. Select appropriate hyperparameters for regularized regression.

A5.3 Extended linear models

a. Understand the assumptions behind different forms of the extended linear model and be able to select the appropriate model, such as: ordinary least squares, generalized linear model, ANOVA, generalized additive models, local regression, lasso ridge regression, partial least squares, and principal component analysis (PCA) regression.

b. Evaluate models developed using the extended linear model approach.

c. Understand the algorithms behind the numerical solutions for the different forms of the extended linear model family to enable interpretation of output from the statistical software employed in modelling and to make appropriate modelling choices when selecting modelling options.

d. Understand and be able to select the appropriate model structure for an extended linear model given the behavior of the dataset to be modelled.

e. Identify the advantages and limitations of modelling techniques.

A5.4 Linear mixed models

a. Understand the assumptions behind linear mixed models and use that understanding to evaluate how to set up a linear mixed-effect model design to best accomplish the goals of the modelling exercise.

b. Understand the algorithms behind the numerical solutions for the linear mixed model to enable interpretation of output from the statistical software employed in modelling to make appropriate choices when evaluating modelling options.

c. Understand and be able to select the appropriate model structure and variable selection for a linear mixed model given the behavior of the dataset to be modelled by interpreting the model diagnostics and/or summary statistics on the variables available in the model, along with any graphs depicting how the dependent variable behaves as a function of possible explanatory variables.

A5.5 Bayesian analysis and Markov chain Monte Carlo

a. Evaluate the different options available when creating and using Bayesian models for a given modelling assignment.

b. Understand how to set up a Bayesian Markov chain Monte Carlo (MCMC) model and evaluate how a given set of design choices affects the results of a model.

c. Understand Bayesian computation, how MCMC methods are used, and how to evaluate model performance.

d. Interpret and calculate diagnostics of simulation performance to evaluate when a given modelling approach should be used.

e. Understand how to apply model checking, evaluation, comparison, and expansion techniques as an aid to interpreting and evaluating model diagnostics.

A5.6 Time-series models

a. Define and explain the concepts and components of stochastic time-series processes, including stationarity and autocorrelation.

b. Describe specific time-series models, including random walk, exponential smoothing, autoregressive, and autoregressive conditionally heteroskedastic.

c. Calculate and interpret predicted values and confidence and prediction intervals.

A5.7 Principal component analysis

a. Define principal components.

b. Interpret the results of a principal component analysis, considering loading factors and proportion of variance explained.

c. Explain uses of principal components.

d. Understand and apply principal component analysis.

A5.8 Decision trees

a. Explain the purpose and uses of decision trees.

b. Explain and interpret decision trees considering regression trees and recursive binary splitting.

c. Explain and interpret bagging, boosting, and random forests.

d. Explain and interpret classification trees, their construction, Gini index, and entropy.

e. Compare decision trees to linear models.

f. Interpret the results of a decision tree analysis.

g. Construct regression and classification trees.

h. Use bagging and random forests to improve accuracy.

i. Use boosting to improve accuracy.

j. Select appropriate hyperparameters for decision trees and related techniques.

A5.9 Cluster analysis

a. Explain the uses of clustering.

b. Explain K-means clustering.

c. Explain hierarchical clustering.

d. Explain methods for deciding the number of clusters.

e. Compare hierarchical with K-means clustering.

A5.10 Predictive analytics problem definition and tools

a. Understand the different types of predictive modelling problems.

b. Write and execute basic commands in R using RStudio or other coding languages.

c. Translate a vague question into one that can be analyzed with statistics and predictive analytics to solve a business problem.

d. Consider factors such as available data and technology, significance of business impact, and implementation challenges to define the problem

A5.11 Data types, exploration, and visualization

a. Identify structured, unstructured, and semi-structured data.

b. Identify the types of variables and terminology used in predictive modelling.

c. Understand basic methods of handling missing data.

d. Implement effective data design with respect to time frame, sampling, and granularity.

e. Apply univariate and bivariate data exploration techniques.

f. Understand the key principles of constructing graphs.

g. Create a variety of graphs using a computer package.

A5.12 Data issues and resolution

a. Evaluate the quality of appropriate data sources for a problem.

b. Identify opportunities to create features from the basic data that may add value.

c. Identify outliers and other data issues.

d. Handle non-linear relationships via transformations.

e. Identify the regulations, standards, and ethics surrounding predictive modelling and data collection.

A5.13 Communication in predictive analytics

a. Develop and justify a recommended analytics solution.

b. Communicate in a clear and straightforward manner using common language that is appropriate for the intended audience.

c. Structure a report in an effective manner.

d. Follow standards of practice for actuarial communication.

References for underlying knowledge applicable to the ACIA modules and Capstone Exam

While there are no formal prerequisites for the ACIA modules, candidates at accredited universities will be expected to have completed identified actuarial courses. Candidates are responsible for ensuring they have the appropriate knowledge. The following reading references outline the key underlying topics that should be secured by candidates as they progress toward the ACIA modules and Capstone Exam.

1. Topics of finance

CIA Syllabus Section	Reference 1	Reference 2
A3.9 Introductory Derivatives – Forwards and Futures	Chapter 3	Chapters 2-5
A3.10 General Properties of Options	Chapters 5-6	Chapters 3-9
A3.11 Binomial Pricing Models	Chapters 9-12	Chapters 10-11
A3.12 Black-Scholes Option Pricing Model	Chapters 16-18	Chapter 12
A3.13a Option Greeks	Chapter 20	Chapter 12
A3.13b Risk Management	Chapter 20	Chapter 13

References:

1. Actuarial Finance: Derivatives, Quantitative Models and Risk Management
   Authors: Mathieu Boudreault, Jean-François Renaud
   ISBN: 978-1-119-13700-9
2. Derivatives Markets, 3rd Edition
   Author: Robert L. McDonald
   ISBN: 978-0-321-54308-0

2. Topics of long-term actuarial mathematics

CIA Syllabus Section	Reference 1
A4.1 Long-Term Insurance Coverages	Chapter 1
A4.2 Survival Models and Their Estimation	Chapters 2, 3 and 18
A4.3 Present Value Random Variables	Chapters 4, 5, 8, 9 and 10
A4.4 Long-Term Insurance Premium Calculation	Chapters 6, 8, 9 and 10
A4.5 Long-Term Insurance Reserves	Chapters 7-10
A4.6 Pension Plans and Retirement Benefits	Chapter 11

Reference:

1. Actuarial Mathematics for Life Contingent Risks, 3rd Edition
   Authors: David C. M. Dickson, Mary R. Hardy, Howard R. Waters
   ISBN: 978-1-108-47808-3

3. Topics of short-term actuarial mathematics

CIA Syllabus Section	Reference 1	Reference 2
A4.7 Severity Models in Short-Term Insurance	Chapters 4 and 5 (Sections 5.1, 5.2.1-5.2.4 and 5.3)	
A4.8 Frequency Models in Short-Term Insurance	Chapter 6	
A4.9 Aggregate Models in Short-Term Insurance	Chapter 9 (excluding Sections 9.6.1 and 9.8.3)	
A4.10 Coverage Modifications in Short-Term Insurance	Chapter 8	
A4.11 Risk Measures	Chapter 3	
A4.12 Construction and Selection of Parametric Models	Chapters 11 (Sections 11.1-11.6), 12 (excluding Section 12.5), 13 and 15 (excluding Section 15.4.2)	
A4.13 Credibility Theory	Chapters 16-18	
A4.14 Short-Term Insurance and Reinsurance Coverages		Chapters 2 and 5 (Sections 5.5.1 and 5.5.2)
A4.15 Pricing and Reserving for Short-Term Insurance Coverages		Chapters 3, 4 and 5 (Sections 5.5.3 and 5.5.4)

References:

1. Loss Models: From Data to Decisions, 5th Edition

   Stuart A. Klugman, Harry H. Panjer, Gordon E. Willmot

   ISBN: 978-1-119-52378-9

2. Introduction to Ratemaking and Loss Reserving for Property and Casualty Insurance, 4th Edition Robert Brown, W. Scott Lennox

   ISBN: 978-1-625-42474-7

4. Topics of predictive analytics and statistics

CIA Syllabus Section	Reference 1	Reference 2	Reference 3
A5.1 Basics of Statistical Learning	Chapters 2 (Sections 1-3) and 5 (Sections 1 and 3)		
A5.2 Generalized Linear Models	Chapters 3 (Sections 1-6), 4 (Sections 1-3 and 6) and 6 (Sections 1-5)	Chapters 2 (Sections 1-8), 3 (Sections 1-5), 5 (Sections 1-7), 11 (Sections 1-6), 12 (Sections 1-4) and 13 (Sections 1-6)	Chapters 1-9, excluding 6.7, 6.8, 7.9
A5.7 Principal Component Analysis	Chapter 12 (Sections 1 and 2)		
A5.8 Decision Trees	Chapter 8 (Sections 1 and 3)		
A5.9 Cluster Analysis	Chapter 12 (Section 4)		
A5.13 Communication in Predictive Analytics		Chapter 6 (Sections 1-5)	

References:

1. An Introduction to Statistical Learning, 2nd Edition
   Authors: Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani
   ISBN: 978-1-0716-1417-4
2. Regression Modeling with Actuarial and Financial Applications
   Author: Edward W. Frees
   ISBN: 978-0-5211-3596-2
3. An Introduction to Generalized Linear Models, 4th Edition
   Authors: Annette J. Dobson, Adrian G. Barnett
   ISBN: 978-1-138-74151-5

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