



**Institute of Actuaries of India**

**Subject**  
**CT1 – Financial Mathematics**  
**For 2018 Examinations**

## **Subject CT1 – Financial Mathematics Core Technical**

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### **Aim**

The aim of the Financial Mathematics subject is to provide a grounding in financial mathematics and its simple applications.

### **Links to other subjects**

Subject CT2 – Finance and Financial Reporting: develops the use of the asset types introduced in this subject.

Subject CT4 – Models: develops the idea of stochastic interest rates.

Subject CT5 – Contingencies: develops some of the techniques introduced in this subject in situations where cashflows are dependent on survival.

Subject CT7 – Business Economics: develops the behaviour of interest rates.

Subject CT8 – Financial Economics: develops the principles further.

Subjects CA1 – Actuarial Risk Management, CA2 – Model Documentation, Analysis and Reporting and the Specialist Technical and Specialist Applications subjects: use the principles introduced in this subject.

### **Objectives**

On completion of the subject the trainee actuary will be able to:

- (i) Describe how to use a generalised cashflow model to describe financial transactions.
  1. For a given cashflow process, state the inflows and outflows in each future time period and discuss whether the amount or the timing (or both) is fixed or uncertain.
  2. Describe in the form of a cashflow model the operation of a zero coupon bond, a fixed interest security, an index-linked security, cash on deposit, an equity, an “interest only” loan, a repayment loan, and an annuity certain.
- (ii) Describe how to take into account the time value of money using the concepts of compound interest and discounting.
  1. Accumulate a single investment at a constant rate of interest under the operation of:
    - simple interest
    - compound interest
  2. Define the present value of a future payment.
  3. Discount a single investment under the operation of simple (commercial) discount at a constant rate of discount.

4. Describe how a compound interest model can be used to represent the effect of investing a sum of money over a period.
- (iii) Show how interest rates or discount rates may be expressed in terms of different time periods.
1. Derive the relationship between the rates of interest and discount over one effective period arithmetically and by general reasoning.
  2. Derive the relationships between the rate of interest payable once per effective period and the rate of interest payable  $p$  times per time period and the force of interest.
  3. Explain the difference between nominal and effective rates of interest and derive effective rates from nominal rates.
  4. Calculate the equivalent annual rate of interest implied by the accumulation of a sum of money over a specified period where the force of interest is a function of time.
- (iv) Demonstrate a knowledge and understanding of real and money interest rates.
- (v) Calculate the present value and the accumulated value of a stream of equal or unequal payments using specified rates of interest and the net present value at a real rate of interest, assuming a constant rate of inflation.
1. Discount and accumulate a sum of money or a series (possibly infinite) of cashflows to any point in time where:
    - the rate of interest or discount is constant
    - the rate of interest or discount varies with time but is not a continuous function of time
    - either or both the rate of cashflow and the force of interest are continuous functions of time
  2. Calculate the present value and accumulated value of a series of equal or unequal payments made at regular intervals under the operation of specified rates of interest where the first payment is:
    - deferred for a period of time
    - not deferred
- (vi) Define and use the more important compound interest functions including annuities certain.
1. Derive formulae in terms of  $i, v, n, d, \delta, i^{(p)}$  and  $d^{(p)}$  for  $a_{\overline{n}|}$ ,  $s_{\overline{n}|}$ ,  $a_{\overline{n}|}^{(p)}$ ,  $s_{\overline{n}|}^{(p)}$ ,  $\ddot{a}_{\overline{n}|}$ ,  $\ddot{s}_{\overline{n}|}$ ,  $\ddot{a}_{\overline{n}|}^{(p)}$ ,  $\ddot{s}_{\overline{n}|}^{(p)}$ ,  $\overline{a}_{\overline{n}|}$  and  $s_{\overline{n}|}$ .

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2. Derive formulae in terms of  $i, v, n, d, \delta, i^{(p)}$  and  $d^{(p)}$  for  ${}_m\angle a_{\overline{n}|}$ ,  ${}_m\angle a_{\overline{n}|}^{(p)}$ ,  ${}_m\angle \ddot{a}_{\overline{n}|}$ ,  ${}_m\angle \ddot{a}_{\overline{n}|}^{(p)}$  and  ${}_m\angle \bar{a}_{\overline{n}|}$ .
  3. Derive formulae in terms of  $i, v, n, \delta, a_{\overline{n}|}$  and  $\ddot{a}_{\overline{n}|}$  for  $(Ia)_{\overline{n}|}$ ,  $(I\ddot{a})_{\overline{n}|}$ ,  $(I\alpha)_{\overline{n}|}$ ,  $(I\bar{\alpha})_{\overline{n}|}$  and the respective deferred annuities.
- (vii) Define an equation of value.
1. Define an equation of value, where payment or receipt is certain.
  2. Describe how an equation of value can be adjusted to allow for uncertain receipts or payments.
  3. Understand the two conditions required for there to be an exact solution to an equation of value.
- (viii) Describe how a loan may be repaid by regular instalments of interest and capital.
1. Describe flat rates and annual effective rates.
  2. Calculate a schedule of repayments under a loan and identify the interest and capital components of annuity payments where the annuity is used to repay a loan for the case where annuity payments are made once per effective time period or  $p$  times per effective time period and identify the capital outstanding at any time.
- (ix) Show how discounted cashflow techniques can be used in investment project appraisal.
1. Calculate the net present value and accumulated profit of the receipts and payments from an investment project at given rates of interest.
  2. Calculate the internal rate of return implied by the receipts and payments from an investment project.
  3. Describe payback period and discounted payback period and discuss their suitability for assessing the suitability of an investment project.
  4. Determine the payback period and discounted payback period implied by the receipts and payments from an investment project.
  5. Calculate the money-weighted rate of return, the time-weighted rate of return and the linked internal rate of return on an investment or a fund.
- (x) Describe the investment and risk characteristics of the following types of asset available for investment purposes:
- fixed interest government borrowings
  - fixed interest borrowing by other bodies

- index-linked government borrowings
  - shares and other equity-type finance
  - derivatives
- (xi) Analyse elementary compound interest problems.
1. Calculate the present value of payments from a fixed interest security where the coupon rate is constant and the security is redeemed in one instalment.
  2. Calculate upper and lower bounds for the present value of a fixed interest security that is redeemable on a single date within a given range at the option of the borrower.
  3. Calculate the running yield and the redemption yield from a fixed interest security (as in 1.), given the price.
  4. Calculate the present value or yield from an ordinary share and a property, given simple (but not necessarily constant) assumptions about the growth of dividends and rents.
  5. Solve an equation of value for the real rate of interest implied by the equation in the presence of specified inflationary growth.
  6. Calculate the present value or real yield from an index-linked bond, given assumptions about the rate of inflation.
  7. Calculate the price of, or yield from, a fixed interest security where the investor is subject to deduction of income tax on coupon payments and redemption payments are subject to the deduction of capital gains tax.
  8. Calculate the value of an investment where capital gains tax is payable, in simple situations, where the rate of tax is constant, indexation allowance is taken into account using specified index movements and allowance is made for the case where an investor can offset capital losses against capital gains.
- (xii) Calculate the delivery price and the value of a forward contract using arbitrage free pricing methods.
1. Define “arbitrage” and explain why arbitrage may be considered impossible in many markets.
  2. Calculate the price of a forward contract in the absence of arbitrage assuming:
    - no income or expenditure associated with the underlying asset during the term of the contract
    - a fixed income from the asset during the term
    - a fixed dividend yield from the asset during the term.

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3. Explain what is meant by “hedging” in the case of a forward contract.
  4. Calculate the value of a forward contract at any time during the term of the contract in the absence of arbitrage, in the situations listed in 2 above.
- (xiii) Show an understanding of the term structure of interest rates.
1. Describe the main factors influencing the term structure of interest rates.
  2. Explain what is meant by the par yield and yield to maturity.
  3. Explain what is meant by, derive the relationships between and evaluate:
    - discrete spot rates and forward rates
    - continuous spot rates and forward rates
  4. Define the duration and convexity of a cashflow sequence, and illustrate how these may be used to estimate the sensitivity of the value of the cashflow sequence to a shift in interest rates.
  5. Evaluate the duration and convexity of a cashflow sequence.
  6. Explain how duration and convexity are used in the (Redington) immunisation of a portfolio of liabilities.
- (xiv) Show an understanding of simple stochastic models for investment returns.
1. Describe the concept of a stochastic interest rate model and the fundamental distinction between this and a deterministic model.
  2. Derive algebraically, for the model in which the annual rates of return are independently and identically distributed and for other simple models, expressions for the mean value and the variance of the accumulated amount of a single premium.
  3. Derive algebraically, for the model in which the annual rates of return are independently and identically distributed, recursive relationships which permit the evaluation of the mean value and the variance of the accumulated amount of an annual premium.
  4. Derive analytically, for the model in which each year the random variable  $(1 + i)$  has an independent log-normal distribution, the distribution functions for the accumulated amount of a single premium and for the present value of a sum due at a given specified future time.
  5. Apply the above results to the calculation of the probability that a simple sequence of payments will accumulate to a given amount at a specific future time.

**END OF SYLLABUS**