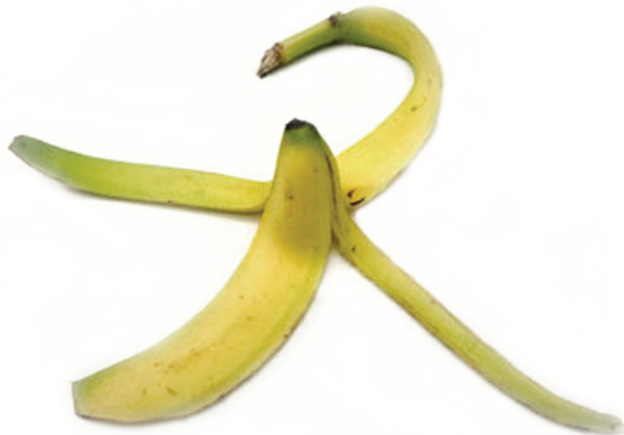


# Exam MLC

## Study Program Guide

Spring 2013 exams

**IMPORTANT**  
Read the "Chapter 11 update"  
at the end of the Study Program Guide  
containing details of an essential SOA update



*Get the most  
from your  
study  
program...*

*... see page 7*

This document contains important information

**Please read this document carefully before starting your study.**

## Contents

1.	About the BPP Study Program	4
2.	Additional help from BPP	6
3.	Getting the most from your BPP study materials	7
4.	Study Skills	9
5.	Calculator advice, examination tables and exam tips	11
6.	Your study session planner	12
7.	Syllabus	19

### *Glossary*

Exam MLC - the life contingencies segment of Exam M.

Exam MFE - the financial economics segment of Exam M.

*Note:* This Study Program Guide relates to Exam MLC only.

## Welcome

We're confident that this BPP Exam MLC study program will have a very positive impact on the way you study for the actuarial exams. We believe that students should spend their time focusing on learning and preparing for the exam, not juggling their time between textbooks, separate solution manuals and then additional study manuals to re-explain those textbooks and solution manuals!

No other provider of actuarial education offers such a wide range of coordinated support, including:

- introductory online lectures
- comprehensive course notes
- online multiple-choice tests
- exam-style question & answer banks
- email tutor support.

We've designed the course to cover all the learning objectives in an order that's right for you. Our course notes provide clear explanations of the syllabus, and include over 390 worked examples and practice questions, all with full solutions.

Our introductory online lectures and online multiple-choice tests are fully coordinated with the course notes. They will ensure that you can get a good introduction to each topic as well as test your knowledge and understanding.

Our question and answer bank contains over 690 exam-style questions to give you the practice necessary to maximize your opportunity for success in the actual examination.

For BPP, providing a study program means providing a commitment to support students all the way through to the exam. Our full-time tutors will answer any questions you may have by email so that you always have the support you need.

Passing the actuarial exams is difficult enough. We understand that you're competing against some very bright people and that it's always hard to find time for studying between working and spending time with friends and family. BPP's study programs organize your study effectively and provide the very best support. They will help you maximize your chances of success in the exam and to make good progress towards qualification.

As you have more contact with BPP, you'll find us to be a very friendly and proactive company. We are committed to providing high quality study support. We respond quickly to students' requests and will do all we can to meet your specific needs. We look forward to helping you.

Good luck with your studying.



David Wilmot  
Director of Education

# 1 About the BPP Exam MLC study program

BPP's Exam MLC study program has everything you need to know, containing 5 coordinated sources of help. Use our study session planner (in Section 6 of this guide) to make sure you get the most from your BPP study program.

## Online lectures

Our introductory online lectures give you a quick start by introducing all of the main topics.

The lectures are coordinated with the BPP course notes to give you the most comprehensive study support available.

You can watch them as many times as you like – as an overview before you study the course notes, or to help you review the material you've just covered.

Either way, together with the course notes they will help you to understand even the most difficult areas of the syllabus.

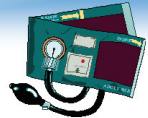

**Example**

A study of retired teachers shows that:

- 8% suffer from migraines
- 12% have high blood pressure
- 93% of migraine sufferers have high blood pressure.

What is the probability that an individual with high blood pressure will suffer from migraines?

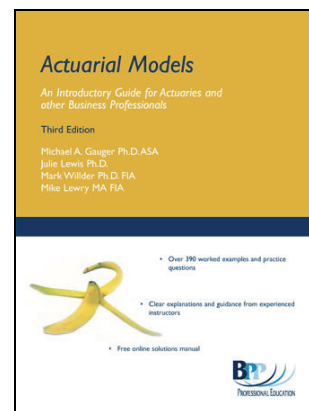
$$\Pr(\text{Migraines} | \text{High BP}) = \frac{\Pr(\text{Migraines})\Pr(\text{High BP} | \text{Migraines})}{\Pr(\text{High BP})}$$

$$= \frac{(0.08)(0.93)}{0.12} = 0.62$$



## Course notes – “Actuarial Models”

These comprehensive notes are divided into 11 chapters to help you structure your progress through the session leading to the exam.

Chapter	Title
1	Introduction to survival models
2	Life insurance models
3	Life annuity models
4	Annual benefit premiums
5	Benefit reserves
6	Multiple life theory
7	Multiple decrement models
8	Insurance models with expenses and profit loadings
9	Discrete-time Markov chains
10	Continuous-time Markov chains
11	Universal life insurances



These course notes include clear explanations of all the main theory plus over 390 worked examples and practice questions (all with full explanatory solutions).

## Online tests

After having read the course notes you can quickly check your knowledge and understanding using our online multiple-choice tests, which include a wide variety of conceptual, computational, and knowledge-based questions. Their online nature is not conducive to long computational problems and so the online test questions are a little more straightforward than you might expect to see on the actual exam. However, they are a great way to work up to the more difficult questions that appear in the question and answer bank.

**BPP Professional Education - Online Testing**  
Interest Theory Chapter 1  
Financial Services  
Question ID : USIT1\_00006

**Question 4 of 20**  
Haley takes out a loan for \$5,000 with an annual effective interest rate of 6.5%. How much interest is payable 18 months from now, assuming no interest is payable before then?

A  \$478.69  
B  \$484.24  
C  \$489.79  
D  \$495.34  
E  \$500.89

<< First < Previous Overview Next > Last >> Unsure  Finish

BPP's online tests contain additional short questions with full solutions. They're coordinated with the course notes and are designed to test all the key concepts that you'll need to know and work you towards answering exam-level questions such as those in our question and answer banks.

## Question & Answer Bank

The question & answer bank contains over 690 exam-style questions. This includes a mix of past exam questions (taken from recent SOA Course M/3 exams) and over 350 original questions written by our team of instructors. We provide a detailed line-by-line solution to every question, to help you learn the techniques required to pass the exam.

The questions are coordinated with the course notes through our study session planner in Section 6 of this Study Program Guide. We list there the questions that you can attempt after completing each chapter of the course notes.

## Email tutor support

Our email support service is designed to help you with the more difficult areas of the course. We'll answer your questions thoroughly and quickly so that you can get on with your studying with no worries. Please refer to the FAQ's section of our website for further guidance regarding email support.

### Getting help with your studying by email

Before submitting questions we do expect students to work through the material carefully and to check first the Course MLC student mailbag at [www.bpptraining.com](http://www.bpptraining.com), as we put answers to **frequently asked questions** about the course material on our website.

If you remain stuck, you can email technical questions about the course material to our team of tutors at: [examMLCsupport@bpp.com](mailto:examMLCsupport@bpp.com)

Please help us to help you by stating your name and your question clearly, with page references if appropriate.

If you have any non-technical questions about BPP's study programs, you should send an email to: [bppUSAinfo@bpp.com](mailto:bppUSAinfo@bpp.com)



## 2 Additional help from BPP

### Practice exams

BPP's practice exams look and feel just like the real thing – they're designed to give you a realistic test of your exam preparation. Each practice exam contains original exam-style questions and is supplied with full explanatory solutions. The practice exams are another helpful source of exam-style questions, especially for students who have worked through all the other questions.

### Flashcards

BPP offers user-friendly flashcards to supplement the study program. They'll help you review and remember the most important formulas, lists, concepts and other pertinent information. Memorizing the important formulas and knowing how to use them are the most effective exam preparation approach for many students, and our flashcards are very helpful in this regard.

### Find out more at [www.bpptraining.com](http://www.bpptraining.com)

For more information on BPP's full range of products and services, visit our website at [www.bpptraining.com](http://www.bpptraining.com).

Our website includes many free samples to download, including course notes, online lectures, and online tests.

You'll also find information on how you can order our products.



## 3 *Getting the most from your study materials*

### *Order of study*

To help you plan your study, we've divided the course into 5 study sessions. The detail of each session appears later in this Study Program Guide, however, each of your study sessions should include four main activities:

**1. Introduction – Watch an online lecture**

The online lectures are designed to introduce the main conceptual ideas and to help you towards understanding the most difficult areas. These introductory online lectures are not a replacement for reading the comprehensive course notes, but they will help you to study more efficiently by identifying the important topics and explaining how the parts of the course are related.

**2. Key learning – Read the related section of the course notes**

The course notes include detailed explanations of the topics covered by the Learning Outcomes, along with over 390 worked examples and practice questions. As you work through the course notes, you should try to study actively and think about what you're reading. (Active study is discussed in the Study Skills section of this Study Program Guide.)

**3. Evaluate learning – Test your understanding**

At the end of each reading there are a number of practice questions. In addition, the online tests include a wide variety of conceptual, computational, and knowledge-based questions. These questions are designed to test your understanding of the syllabus. Most of them are shorter and more straightforward than genuine exam-style questions, but every question is designed to test a concept, technique or formula that you will need to know in order to pass the exam.

**4. Practice answering exam-level questions – question & answer bank**

After learning the important concepts and formulas, the most important way to prepare for the exam is to practice exam-style questions. The other tasks in each study session are designed to help you reach the standard required to attempt these longer and more difficult questions. The question & answer bank contains a large mixture of relevant past exam and brand new questions, all with full explanatory solutions plus hints and tips.

It's a fact that people are more likely to remember something if they review it periodically. So, do look over the chapters you have studied so far from time to time. You may also find it useful to review the online lectures and online tests (where purchased).

The secret to success in preparing for actuarial exams is to practice, practice, and then practice some more!

## *Focus of study*

When studying for Exam MLC, it is generally worth remembering that the later chapters of the course build on the earlier ones. You must get to grips with the basic products and notation before you can tackle the harder material. We recommend that you attach the same level of importance to each chapter.

## *Un-examinable topics*

While you study, it is worth bearing in mind that knowledge of proofs is highly unlikely to be tested within a multiple-choice examination. Although memorizing the proofs of key theorems may not be good use of your time, working through such proofs is often worthwhile as you will learn something that may be required in a new style (more conceptual) question that requires first-principles thinking.



## 4 Study skills

### Overall study plan

A good study plan is one that is:

- developed right at the start of your studies
- realistic
- builds in time for relaxation
- allows for known future busy work periods that will restrict your study time
- allows some time for contingencies.

Once you have set your plan, be determined to stick to it.

Manage your study to allow plenty of time for the concepts you meet in this course to become ingrained in your mind. The most successful students will have completed the course in good time, and left 6-8 weeks for question practice and review. By finishing the course as quickly as possible, you will have a much clearer view of the big picture. It will also allow you to structure your review so that you can concentrate on the important and difficult areas of the course. How often do you think *"I'm just getting the hang of this, I wish the exam was two weeks later"*?

An old rule of thumb that many students use when preparing for actuarial exams is to allocate 100 hours of study time for each hour of exam time. While some students don't need this much time to prepare, other students require more. It is difficult to actually invest this much time over the study cycle, so it is imperative that you start your studies early and stick to your study plan. We provide a sample study plan in Section 6 of this Study Program Guide. Of course, you should monitor your progress over time so that you can determine whether or not you need to significantly ramp up your study time at some point before the exam.

### Study sessions

DO only those activities that will increase your chance of passing, *eg this might not include repeated re-reading of the course notes!*

DO have a specific purpose for each study session, *eg "Read pages 117-126 and attempt questions 35-42 from the question & answer bank"*.

DON'T include non-specific activities, including those using just a time-based target *eg "Three hours studying the material in Chapter 2"*.

DON'T spend too much time reviewing material that you already understand. *You will only improve your chances of passing the exam by getting on top of the material that you currently find difficult.*

DO study somewhere quiet and free from distractions, *eg a library or a desk at home dedicated to study.*

DO study at the time of day (or night!) when you operate at your peak.

DO take short breaks during your study to remain focused. *It's definitely time for a short break if you find that your brain is tired and that your concentration has started to drift from the information in front of you.*

## Active study

Whether you are learning new material or answering questions, you should try to study as actively as possible. This will help you to remain focused on the task, and to ensure that you learn from the process. Here are some techniques that will help you to study actively.

- **Don't believe everything you read!** Good students tend to question everything that they read. They will ask "why, when, how?" when confronted with a new concept, and they will apply their own judgment.
- As you read the course notes, **think of possible questions that the examiners could ask.** This will help you to understand the examiners' point of view and should mean that there are fewer nasty surprises in the exam room. Try to think of possible variations to existing questions too. Designing your own questions on a topic that you find difficult will help you understand it better when you see what it takes to write a reasonable question. Share these questions with colleagues preparing for Exam MLC.
- **Annotate your notes** with your own ideas and questions. This will make your study more active and will help when you come to review the material. Do not simply copy out the notes without thinking about the issues.
- Attempt the end-of-chapter questions as you work through the course. Write down your answer before you check against the solution. Attempt other questions on a similar basis, *ie* write down your answer before looking at the solution provided. **Attempt questions under exam conditions** so as to force you to think and act in a way that is similar to how you will behave in the exam.

## Review stage

- **Attempt as many exam-style questions as you can** – make sure you write down your answers before looking at the solutions provided! It is crucial at this stage that you attempt questions under exam conditions so as to force you to think and act in a way that is similar to how you will behave in the exam.

Recent exam questions have required greater conceptual understanding than the older ones. So don't try to memorize your way through this test. Conceptual understanding will be vital to your success on exam day if the questions you are confronted with are not easily identified as variations on past questions that you have practiced.

- **Take a practice exam** a few weeks before the real exam to identify your weaknesses and work to improve them. You could use one of the original practice exams written by BPP.

## 5 *Calculator advice and general exam tips*

### *Calculator advice*

For Exam MLC you should use the same calculator that you used for Exam FM. Interest rate conversions are occasionally required as are annuity calculations using the cash flow keys. There are no great new calculator tricks to learn for Exam MLC, but we will mention an efficient way to use the calculator memory registers for certain problems involving a discrete random variable with 3 or 4 possible values.

You can read our **calculator advice document** in the Exam FM student resources section of our website [www.bpptraining.com](http://www.bpptraining.com) for:

- advice on which calculator(s) to use in the exam
- shortcuts that will help you use a calculator efficiently with interest conversion and annuities certain
- examples of how to use a calculator with exam-style questions.

### *Examination tables*

You should practice working questions using the tables you will receive in the examination room. **These can be downloaded from the SOA's website ([www.SOA.org](http://www.SOA.org)).**

The Illustrative Table provides a mortality model as well as columns that are useful with the discrete random variables associated with a unit benefit whole life insurance or life annuity due of 1 per year. Other general relations can be used in conjunction with table entries to analyze discrete time models of deferred insurances and annuities, term and endowment insurances, and temporary annuities. If the Table is used in conjunction with the UDD assumption (a device introduced in Chapter 1 that extends a discrete model to a continuous one) then continuous insurances and annuities can be evaluated as well. These ideas are discussed in Chapters 2-5 of the Course Notes and will be encountered in questions in the Q&A Bank. Understanding these ideas is vital for exam success.

### *General exam tips*

Our booklet '**The BPP Guide to Exam Success**' contains lots of great tips for maximizing your chances of success in the exam. Take time to look at this now, so you can practice the appropriate skills throughout your studying, rather than leave it until close to the exam when it will be too late to do so. The booklet can be viewed freely on our website.

Further hints, tips and advice is contained within the individual study session pages in the next section of this Study Program Guide.

## 6 Your study session planner

### Overall study plan

You should set a study plan that is *realistic for you*, based on when you start studying for the exam, your prior knowledge, and other commitments.

Here is a *sample* study plan based on a start date in January 2013. There is a lot of material to get through so *starting on an earlier date would be prudent*. This is especially true if you are also studying for Exam MFE!!

Weeks #	Week beginning	Activity
1-2	January 7	Study session 1
3-4	January 21	Study session 2
5-6	February 4	Study session 3
7	February 18	Review study sessions 1-3 (Work in Q&A bank)
8-9	February 25	Study session 4
10-11	March 11	Study session 5
12	March 25	Contingency for holidays, unexpected events, catch-up <i>etc</i>
13	April 1	Review study sessions 4 and 5 (Work in Q&A bank)
14	April 8	<b>Review period</b> Focus on practicing exam-style questions from the Q&A Bank (including the review section) under time pressure and memorizing unintuitive formulas that cannot be written down from a conceptual understanding.  Attempt a BPP practice exam.  Identify your weaknesses and work to eliminate them.
15	April 15	
16	April 22	
17	April 29	
18	May 6	Exam MLC examination ( <i>May 9 on tentative SOA schedule</i> )

### Planning your study sessions

The following pages are designed to help you plan each of your study sessions in order to make steady progress through the course.

Take care! It is much more important to get through all of the material, reviewing it several times, and to work through a lot of exam-style questions. The potential trap is for you to get bogged down in one area with the result that you don't then have time for a thorough review of all of the material.

# Study record

Use this table to record your progress. Enter the date you complete each task and study session.

	Study Session									
	1	2	3	4	5					
<p><b>Online lectures</b></p> <p>Watch BPP's online lecture for each study session. Each lecture provides an overview of the relevant topics.</p>										
<p><b>Reading</b></p> <p>Read the relevant section of the course notes (the session pages that follow tell you what to read). Work through end-of-chapter questions to test your understanding. We recommend saving the questions marked SOA/CAS for the 6-week review period.</p>										
<p><b>Online multiple choice tests</b></p> <p>Attempt BPP's multiple choice test for each study session. The tests focus on the key concepts you'll need to pass the exam through a series of short, multiple choice questions.</p>										
<p><b>Question &amp; answer bank</b></p> <p>Attempt questions from the question &amp; answer bank for the chapters you have just read. The question &amp; answer bank contains exam-style questions, including a mixture of past exam and original questions. You may like to leave some of the questions for your review.</p>										

# Study session 1



This session covers:

- an introduction to survival models
- life insurance models.

*Required reading:* Chapters 1 and 2 of the BPP course notes.

## Hints, tips and advice

**Important topics** in this area are:

1. life expectancy
2. interpolation methods
3. insurance random present value variables (probabilities, APV's and variances)
4. "special insurances" (exam terminology indicating non-level benefits and the necessity of working from first principles rather than memorized formulas).

In the course notes, we've placed a box around the important formulas to help you identify them for your review. (During the exam, you won't have time to derive many formulas, so by the exam it is important to be able to write them down from solid conceptual understanding or to have memorized the most difficult and unintuitive ones!).

**References** to prior knowledge that is assumed and used in this area:

1. PDFs, CDFs, moment calculation (Exam P)

**Calculator techniques/shortcuts/exam hints:**

1. The UDD assumption results in a piece-wise linear graph for the life table, the survival function, and the CDF. Areas beneath the survival graph for life expectancy problems can be calculated from trapezoids rather than integration.
2. When given data such as  $q_x=0.10$ ,  ${}_2q_x=0.20$ ,  ${}_3q_x=0.30$  create a life table that is consistent with these data ( $l_x=100$ ,  $l_{x+1}=90$ ,  $l_{x+2}=80$ ,  $l_{x+3}=70$ ) so that probabilities can be determined intuitively and interpolation is simple.
3. For a non-level 3-year term insurance, the random present value variable is discrete with 4 possible values (it is zero with probability  ${}_3p_x$ ). Enter the 3 non-zero values in memory registers 1-3, and the corresponding probabilities in memory registers 4-6. Then you are in good position to compute the first two moments of the distribution.
4. The deferred insurance APV ( ${}_n|A_x = {}_nE_x A_{x+n}$ ) is one step beyond the Illustrative Life Table (exam Tables). Term insurance requires two steps ( $A_{x:\overline{n}|}^1 = A_x - {}_nE_x A_{x+n}$ ).

## 7 Syllabus

The Syllabus is an important part of your study. You should review this Syllabus at the start and when you have completed your exam preparations to make sure that you understand what you are required to know for the exam.

### *Learning Objectives and Learning Outcomes*

- 1) Describe the common decrements and their application to assurances and annuities.
- 2) Models used to model decrements used in insurances and annuities.
  - a. Calculate single, joint, marginal and conditional probabilities, as applicable, and moments for the time-to-decrement, age-at-decrement and cause-of-decrement random variables based on single decrement on single life models, multiple decrements on single life models and single decrement on multiple lives models.
  - b. Calculate the probability of being in a particular state and transitioning between states based on continuous-time Markov chain models, discrete approximations of continuous-time Markov chain models and discrete-time Markov chain models.
- 3) Calculate present values and accumulated values using non-stochastic interest rate models.
- 4) Models used to model cash flows of traditional life insurances and annuities.
  - a. Calculate single, joint, marginal and conditional probabilities, as applicable, and moments of the present-value-of-benefits and present-value-of-premium random variables based on single decrement on single life models, multiple decrements on single life models and single decrement on multiple lives models.
  - b. Calculate present values of cash flows.
  - c. Calculate present values of cash flows by redefining the present-value-of-benefit and present-value-of-premium random variables to Markov chain models.
- 5) Describe how reserves are used as an accounting entry to allocate income over the life of a contract.
- 6) Benefit reserves for traditional life insurances and annuities.
  - a. Calculate moments of the loss-at-issue and future-loss random variables based on single decrement on single life models and multiple decrements on single life models.
  - b. State the equivalence principle.
  - c. Calculate benefit reserves and premiums based on single decrement on single life models and multiple decrements on single life models.
  - d. Calculate the benefit reserves and premiums using a Markov chain model with specified cash flows.
- 7) Models used to model cash flows for non-interest sensitive insurances other than traditional life insurances and annuities.
  - a. Calculate benefit premiums and benefit reserves by applying concepts presented for traditional life insurance and annuities for the loss-at-issue and future-loss random variables based on single decrement on single life models, multiple decrements on single life models, and Markov chain models.

- 8) Models used to model contract cash flows for basic universal life insurances.
  - a. Calculate the contract account value and contract surrender value.
  - b. Describe differences between primary and secondary contract guarantees.
- 9) Models used to model cash flows of basic universal life insurance.
  - a. Calculate probabilities and moments of the present-value-of-benefits, present-value-of-premiums and present-value-of-charges random variables based on multiple decrements on single life models.
  - b. Calculate present value of cash flows.
  - c. Redefine the present-value-of-benefit and present-value-of-premium random variables to Markov chain models to calculate present values of cash flows.
- 10) Benefit reserves for basic universal life insurances.
  - a. Calculate the benefit reserve.
  - b. Describe the calculation of the reserve for a secondary guarantee.
- 11) Models that consider expense cash flows.
  - a. Calculate an expense factor using the appropriate exposure.
  - b. Calculate probabilities and moments of the present-value-of-expenses random variable based on single decrement on single life models and multiple decrements on single life models.
  - c. Calculate the expense reserve.
  - d. Calculate a gross premium given expenses and benefits based on: the equivalence principle; a return on gross profits basis.
  - e. Calculate the gross premium reserve.
  - f. Calculate the asset share.



## Chapter 11 update – April 2012

After the publication of the third edition of *Actuarial Models: An Introductory Guide for Actuaries and other Business Professionals*, the Society of Actuaries published further information regarding the MLC exam on its website.

In particular, the Society's website now includes a "Notation and Terminology" note (see <http://www.soa.org/files/edu/edu-2012-spring-mlc-terminology.pdf>) and an updated set of sample questions and solutions (see <http://www.soa.org/files/edu/edu-2012-spring-mlc-questions.pdf> and <http://www.soa.org/files/edu/edu-2012-spring-mlc-solutions.pdf>). Questions 296 and 297 of the sample questions cover the topic of universal life insurances.

The Society's documents follow a slightly different approach for universal life insurances than that followed in Chapter 11 of the textbook. We would strongly recommend that you read these documents carefully and check the Society's website periodically for further updates (see the "Syllabus and Study Materials" information at <http://www.soa.org/education/exam-req/edu-exam-m-detail.aspx>).

On page 4 of the Notation and Terminology note is a helpful table of the different terminology in common use alongside the term that will be used in the exam. For example, you will see that what we have described as a mortality charge in the textbook will be referred to as cost of insurance in the exam.

The most important difference in approach is in the calculation of the mortality charge, and we discuss this in more detail in the remainder of this update. In the Society's documents, the mortality charges are based on the contract fund value at the end of the period. However, mortality charges are based on the contract fund value at the start of the period in the textbook.

Both approaches to calculating mortality charges are used in practice. The Notation and Terminology note recognizes this, but says that the approach given in the note should be used when attempting exam questions unless otherwise specified. We have updated the question and answer bank to include questions using both approaches to give you practice in using the various approaches that might come up in the exam.

### *Contract fund value*

The Notation and Terminology note gives the following equation for the calculation of the contract fund value (which will be referred to as the **account value** in the exam):

$$AV_{end} = (AV_{start} + P(1-f) - e - COI)(1+i^c)$$

Converting this to the notation used in the textbook we obtain:

$$V_t = (V_{t-1} + P - EC_t - MC_t)(1+i^c)$$

where  $EC_t = Pf + e$  and  $i^c$  is the credited interest rate in the period.

The equation we gave in the textbook was:

$$V_t = (V_{t-1} + P_t - EC_t - MC_t)(1+i_t) - IC_t$$

So, we can see that the Society's approach is basically identical to the textbook. The Society has separated the expense charges into expense charges that are a percentage of the premium ( $Pf$ )

and expense charges that are per policy ( $e$ ). In the textbook we have otherwise given a more general formula by including an explicit investment charge (the Society's formula assumes that this is charged by reducing the interest rate credited to the policy) and adding subscripts to indicate that each term is time dependant.

### ***Mortality charge***

The Notation and Terminology note gives the following equation for the calculation of the mortality charge (which will be referred to as the **cost of insurance** in the exam):

$$COI = \frac{DB_{end} - AV_{end}}{1 + i^q} (\text{coi rate})$$

Converting this to the notation used in the textbook we obtain:

$$MC_t = \frac{DB_t - V_t}{1 + i^q} \times q_{x+t-1}$$

where  $DB_t$  is the projected death benefit at the end of the period and  $i^q$  is the rate used for discounting in the mortality charge calculation (assuming that benefits are paid at the end of the period). For example,  $DB_t = F_t$  if the death benefit is equal to the face value, and  $DB_t = F_t + V_t$  if the death benefit is equal to the face value plus the contract fund value.

If the death benefit is equal to the face value plus the contract fund value then the mortality charge given by the textbook is:

$$MC_t = F_t \times q_{x+t-1}$$

This is the same as the equation given by the Society except that the textbook has set  $i^q$  to zero (the impact of this discounting can often be ignored, especially if benefits are paid immediately on death and charges are deducted on a monthly basis).

If the death benefit is equal to the face value then the mortality charge given by the textbook is:

$$MC_t = [F_t - (V_{t-1} + P_t - EC_t)] \times q_{x+t-1}$$

This differs from the Society's approach in two ways. Firstly, the discounting is missing as above. Secondly, the textbook bases the mortality charge on the contract fund value at the beginning of the period, whereas the Society bases it on the contract fund value at the end of the period (assuming that the death benefit is paid at the end of the period). Note that the Society's approach would be harder to apply in practice because the contract fund value at the end of the period would need to be estimated in order to calculate the mortality charge at the start of the period.

### ***Corridor factors***

In the textbook we noted that, for tax reasons, the death benefit may be increased if necessary to ensure that it is always greater than the contract fund value by a sufficient amount. This amount is referred to as a **corridor factor**. It may vary with the policyholder's age and may be expressed as a percentage of the contract fund value.

The Notation and Terminology note gives the following example. Consider a universal life contract that pays out the larger of the contract fund value and a face value of 50,000, but also contains a corridor factor of 200%. Then the death benefit will be the greater of 50,000 and 200% of the contract fund value. If the contract fund value was 30,000, the death benefit would be the higher of 50,000 and 200% of 30,000, so it would be 60,000. Similarly if the contract fund value was 20,000, the death benefit would be the higher of 50,000 and 200% of 20,000, so it would be 50,000.

If  $CF_t$  represents the corridor factor, then the death benefit is given by the following:

$$DB_t = \max\left(F_t, V_t \times \frac{CF_t}{100\%}\right)$$

If the death benefit is larger than the contract fund value then this amount must be charged for. The mortality charge can be expressed as follows:

$$MC_t = \frac{DB_t - V_t}{1 + i^q} \times q_{x+t-1}$$

$$= \left[ \max\left(F_t - V_t, V_t \times \frac{(CF_t - 100\%)}{100\%}\right) \right] \times \frac{q_{x+t-1}}{1 + i^q}$$

Note that if the corridor factor is greater than 100%, then the death benefit will always be larger than the contract fund value and a mortality charge will be payable. This ensures that there is always an element of life insurance so that the contract retains its tax advantages.

### ***Mortality charges at the end of the period***

The Notation and Terminology note says that it will usually be assumed that  $i^q = i^c$ . In this case (using the notation of the textbook) we have:

$$V_t = (V_{t-1} + P - EC_t - MC_t)(1 + i^c)$$

$$= \left( V_{t-1} + P - EC_t - \frac{DB_t - V_t}{1 + i^q} \times q_{x+t-1} \right) (1 + i^c)$$

$$= (V_{t-1} + P - EC_t)(1 + i^c) - (DB_t - V_t) \times q_{x+t-1}$$

This is effectively the same as deducting the mortality charge at the end of the period.

Deducting the mortality charge at the end of the period has the advantage that the contract fund value is known at the point the death benefit is paid (if the death benefit is also paid at the end of the period).

### ***Similarity to the benefit reserve for a term insurance***

If the death benefit is equal to the face value,  $i^q = i^c$ , and there is no investment charge, then we have the following equation for the contract fund value:

$$V_t = (V_{t-1} + P_t - EC_t)(1 + i_t) - (F_t - V_t) \times q_{x+t-1}$$

Note that this is the same as the recursive equation for the benefit reserve for a term insurance with death benefit  $F_t$  and premium  $P_t - EC_t$ .

Also note that  $V_t$  occurs on both the left and the right of the equation. To solve the equation for  $V_t$  you need to rearrange as follows:

$$V_t = \frac{(V_{t-1} + P_t - EC_t)(1 + i_t) - F_t \times q_{x+t-1}}{1 - q_{x+t-1}}$$

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