



Society of Actuaries



Canadian Institute of Actuaries

Exam MLC Models for Life Contingencies

Thursday,
May 9, 2013
8:30 a.m. – 11:45 a.m.

MLC

INSTRUCTIONS TO CANDIDATES

1. Write your candidate number here _____. Your name must not appear.
2. Do not break the seal of this book until the supervisor tells you to do so.
3. Tables and numerical values necessary for solving some of the questions on this examination will be distributed by the Supervisor.
4. This examination consists of 25 multiple-choice questions.
5. Each question has equal weight. Your score will be based on the number of questions which you answer correctly. No credit will be given for omitted answers and no credit will be lost for wrong answers; hence, you should answer all questions even those for which you have to guess.
6. A separate answer sheet is inside the front cover of this book. During the time allotted for this examination, record all your answers on side 2 of the answer sheet. **NO ADDITIONAL TIME WILL BE ALLOWED FOR THIS PURPOSE.** No credit will be given for anything indicated in the examination book but not transferred to the answer sheet. Failure to stop writing or coding your answer sheet after time is called will result in the disqualification of your answer sheet or further disciplinary action.
7. Five answer choices are given with each question, each answer choice being identified by a key letter (A to E). Answer choices for some questions have been rounded. For each question, blacken the oval on the answer sheet which corresponds to the key letter of the answer choice that you select.
8. Use a soft-lead pencil to mark the answer sheet. To facilitate correct mechanical scoring, be sure that, for each question, your pencil mark is dark and completely fills only the intended oval. Make no stray marks on the answer sheet. If you have to erase, do so completely.
9. Do not spend too much time on any one question. If a question seems too difficult, leave it and go on.
10. While every attempt is made to avoid defective questions, sometimes they do occur. If you believe a question is defective, the supervisor or proctor cannot give you any guidance beyond the instructions on the exam booklet.
11. Clearly indicated answer choices in the test book can be an aid in grading examinations in the unlikely event of a lost answer sheet.
12. Use the blank portions of each page for your scratch work. Extra blank pages are provided at the back of the examination book.
13. When the supervisor tells you to do so, break the seal on the book and remove the answer sheet.

On side 1 of the answer sheet, space is provided to write and to code candidate information. Complete Blocks A through G as follows:
 - (a) in Block A, print your name and the name of this test center;
 - (b) in Block B, print your last name, first name and middle initial and code your name by blackening the ovals (one in each column) corresponding to the letters of your name; for each empty box, blacken the small rectangle immediately above the "A" oval;
 - (c) write your candidate number in Block C (as it appears on your ticket of admission for this examination) and write the number of this test center in Block D (the supervisor will supply the number);
 - (d) code your candidate number and center number by blackening the five ovals (one in each column) corresponding to the five digits of your candidate number and the three ovals (one in each column) corresponding to the three digits of the test center number, respectively. Please be sure that your candidate number and the test center number are coded correctly;
 - (e) in Block E, code the examination that you are taking by blackening the oval to the left of "Exam MLC";
 - (f) in Block F, blacken the appropriate oval to indicate whether you are using a calculator and write in the make and model number; and
 - (g) in Block G, sign your name and write today's date. If the answer sheet is not signed, it will not be graded.

On side 2 of your answer sheet, space is provided at the top for the number of this examination book. Enter the examination book number, from the upper right-hand corner of this examination book, in the four boxes at the top of side 2 marked "BOOKLET NUMBER".
14. After the examination, the supervisor will collect this book and the answer sheet separately. **DO NOT ENCLOSE THE ANSWER SHEET IN THE BOOK.** All books and answer sheets must be returned. **THE QUESTIONS ARE CONFIDENTIAL AND MAY NOT BE TAKEN FROM THE EXAMINATION ROOM.**

****BEGINNING OF EXAMINATION****

- 1.** For a fully discrete whole life insurance of 1000 on (30), you are given:
- (i) Mortality follows the Illustrative Life Table.
 - (ii) $i = 0.06$
 - (iii) The premium is the benefit premium.

Calculate the first year for which the expected present value at issue of that year's premium is less than the expected present value at issue of that year's benefit.

- (A) 11
- (B) 15
- (C) 19
- (D) 23
- (E) 27

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2. P&C Insurance Company is pricing a special fully discrete 3-year term insurance policy on (70). The policy will pay a benefit if and only if the insured dies as a result of an automobile accident.

You are given:

(i)

x	$I_x^{(\tau)}$	$d_x^{(1)}$	$d_x^{(2)}$	$d_x^{(3)}$	Benefit
70	1000	80	10	40	5,000
71	870	94	15	60	7,500
72	701	108	18	82	10,000

where $d_x^{(1)}$ represents deaths from cancer, $d_x^{(2)}$ represents deaths from automobile accidents, and $d_x^{(3)}$ represents deaths from all other causes.

(ii) $i = 0.06$

(iii) Level premiums are determined using the equivalence principle.

Calculate the annual premium.

- (A) 122
- (B) 133
- (C) 144
- (D) 155
- (E) 166

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3. For a special fully discrete 20-year endowment insurance on (40) , you are given:

- (i) The only death benefit is the return of annual benefit premiums accumulated with interest at 6% to the end of the year of death.
- (ii) The endowment benefit is 100,000.
- (iii) Mortality follows the Illustrative Life Table.
- (iv) $i = 0.06$

Calculate the annual benefit premium.

- (A) 2365
- (B) 2465
- (C) 2565
- (D) 2665
- (E) 2765

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4. Employment for Joe is modeled according to a two-state homogeneous Markov model with states:

Actuary (Ac)
Professional Hockey Player (H)

You are given:

- (i) Transitions occur December 31 of each year. The one-year transition probabilities are:

$$\begin{array}{c} \text{Ac} \\ \text{H} \end{array} \begin{bmatrix} \text{Ac} & \text{H} \\ 0.4 & 0.6 \\ 0.8 & 0.2 \end{bmatrix}$$

- (ii) Mortality for Joe depends on his employment:

$$q_{35+k}^{Ac} = 0.10 + 0.05k, \quad \text{for } k = 0, 1, 2$$

$$q_{35+k}^H = 0.25 + 0.05k, \quad \text{for } k = 0, 1, 2$$

- (iii) $i = 0.08$

On January 1, 2013, Joe turned 35 years old and was employed as an actuary. On that date, he purchased a 3-year pure endowment of 100,000.

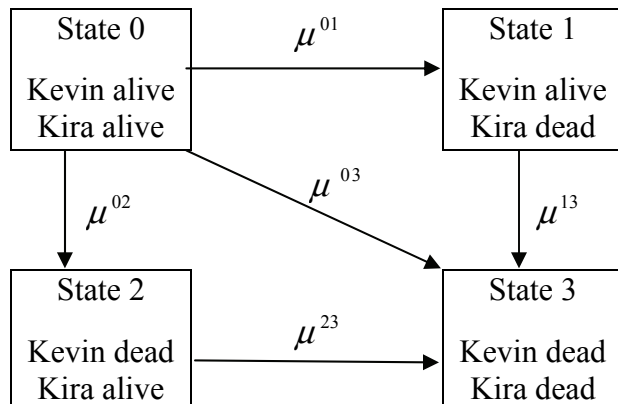
Calculate the expected present value at issue of the pure endowment.

- (A) 32,510
(B) 36,430
(C) 40,350
(D) 44,470
(E) 48,580

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5. The joint lifetime of Kevin, age 65, and Kira, age 60, is modeled as:



You are given the following constant transition intensities:

- (i) $\mu^{01} = 0.004$
- (ii) $\mu^{02} = 0.005$
- (iii) $\mu^{03} = 0.001$
- (iv) $\mu^{13} = 0.010$
- (v) $\mu^{23} = 0.008$

Calculate ${}_{10}p_{65:60}^{02}$.

- (A) 0.046
- (B) 0.048
- (C) 0.050
- (D) 0.052
- (E) 0.054

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6. For a wife and husband ages 50 and 55, with independent future lifetimes, you are given:

- (i) The force of mortality on (50) is $\mu_{50+t} = \frac{1}{50-t}$, for $0 \leq t < 50$.
- (ii) The force of mortality on (55) is $\mu_{55+t} = 0.04$, for $t > 0$.
- (iii) For a single premium of 60, an insurer issues a policy that pays 100 at the moment of the first death of (50) and (55).
- (iv) $\delta = 0.05$

Calculate the probability that the insurer sustains a positive loss on the policy.

- (A) 0.45
- (B) 0.47
- (C) 0.49
- (D) 0.51
- (E) 0.53

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7. You are given:

(i) $q_{60} = 0.01$

(ii) Using $i = 0.05$, $A_{60:\overline{3}|} = 0.86545$.

Using $i = 0.045$, calculate $A_{60:\overline{3}|}$.

(A) 0.866

(B) 0.870

(C) 0.874

(D) 0.878

(E) 0.882

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8. For a special increasing whole life insurance on (40) , payable at the moment of death, you are given:

(i) The death benefit at time t is $b_t = 1 + 0.2t$, $t \geq 0$

(ii) The interest discount factor at time t is $v(t) = (1 + 0.2t)^{-2}$, $t \geq 0$

(iii) ${}_t p_{40} \mu_{40+t} = \begin{cases} 0.025, & 0 \leq t < 40 \\ 0, & \text{otherwise} \end{cases}$

(iv) Z is the present value random variable for this insurance.

Calculate $\text{Var}(Z)$.

(A) 0.036

(B) 0.038

(C) 0.040

(D) 0.042

(E) 0.044

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9. For a fully discrete whole life insurance of 10,000 on (x) , you are given:

- (i) Deaths are uniformly distributed over each year of age.
- (ii) The benefit premium is 647.46 .
- (iii) The benefit reserve at the end of year 4 is 1405.08 .
- (iv) $q_{x+4} = 0.04561$
- (v) $i = 0.03$

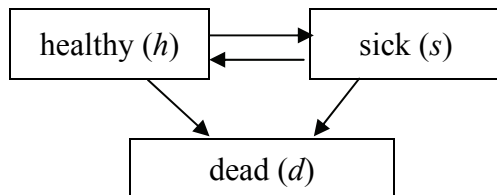
Calculate the benefit reserve at the end of 4.5 years.

- (A) 1570
- (B) 1680
- (C) 1750
- (D) 1830
- (E) 1900

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10. A multi-state model is being used to value sickness benefit insurance:



For a policy on (x) you are given:

- (i) Premiums are payable continuously at the rate of P per year while the policyholder is healthy.
- (ii) Sickness benefits are payable continuously at the rate of B per year while the policyholder is sick.
- (iii) There are no death benefits.
- (iv) μ_{x+t}^{ij} denotes the intensity rate for transition from i to j , where $i, j = s, h$ or d .
- (v) δ is the force of interest.
- (vi) ${}_tV^{(i)}$ is the reserve at time t for an insured in state i where $i = s, h$ or d .

Which of the following gives Thiele's differential equation for the reserve that the insurance company needs to hold while the policyholder is sick?

- (A) $\frac{d}{dt} {}_tV^{(s)} = \delta {}_tV^{(s)} + B - \mu_{x+t}^{sh} ({}_tV^{(h)} - {}_tV^{(s)})$
- (B) $\frac{d}{dt} {}_tV^{(s)} = \delta {}_tV^{(s)} - B - \mu_{x+t}^{sh} ({}_tV^{(h)} - {}_tV^{(s)})$
- (C) $\frac{d}{dt} {}_tV^{(s)} = \delta {}_tV^{(s)} + B - \mu_{x+t}^{sh} ({}_tV^{(h)} - {}_tV^{(s)}) - \mu_{x+t}^{sd} {}_tV^{(s)}$
- (D) $\frac{d}{dt} {}_tV^{(s)} = \delta {}_tV^{(s)} - B - \mu_{x+t}^{sh} ({}_tV^{(h)} - {}_tV^{(s)}) - \mu_{x+t}^{sd} {}_tV^{(s)}$
- (E) $\frac{d}{dt} {}_tV^{(s)} = \delta {}_tV^{(s)} - B - \mu_{x+t}^{sh} ({}_tV^{(h)} - {}_tV^{(s)}) + \mu_{x+t}^{sd} {}_tV^{(s)}$

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11. For a one-year term insurance on (45), whose mortality follows a double decrement model, you are given:

- (i) The death benefit for cause (1) is 1000 and for cause (2) is F .
- (ii) Death benefits are payable at the end of the year of death.
- (iii) $q_{45}^{(1)} = 0.04$ and $q_{45}^{(2)} = 0.20$
- (iv) $i = 0.06$
- (v) Z is the present value random variable for this insurance.

Calculate the value of F that minimizes $\text{Var}(Z)$.

- (A) 0
- (B) 50
- (C) 167
- (D) 200
- (E) 500

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12. Russell entered a defined benefit pension plan on January 1, 2000, with a starting salary of 50,000. You are given:

- (i) The annual retirement benefit is 1.7% of the final three-year average salary for each year of service.
- (ii) His normal retirement date is December 31, 2029.
- (iii) The reduction in the benefit for early retirement is 5% for each year prior to his normal retirement date.
- (iv) Every January 1, each employee receives a 4% increase in salary.
- (v) Russell retires on December 31, 2026.

Calculate Russell's annual retirement benefit.

- (A) 49,000
- (B) 52,000
- (C) 55,000
- (D) 58,000
- (E) 61,000

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13. An automobile insurance company classifies its insured drivers into three risk categories. The risk categories and expected annual claim costs are as follows:

Risk Category	Expected Annual Claim Cost
Low	100
Medium	300
High	600

The pricing model assumes:

- At the end of each year, 75% of insured drivers in each risk category will renew their insurance.
- $i = 0.06$
- All claim costs are incurred mid-year.

For those renewing, 70% of Low Risk drivers remain Low Risk, and 30% become Medium Risk. 40% of Medium Risk drivers remain Medium Risk, 20% become Low Risk, and 40% become High Risk. All High Risk drivers remain High Risk.

Today the Company requires that all new insured drivers be Low Risk. The present value of expected claim costs for the first three years for a Low Risk driver is 317. Next year the company will allow 10% of new insured drivers to be Medium Risk.

Calculate the percentage increase in the present value of expected claim costs for the first three years per new insured driver due to the change.

- (A) 14%
- (B) 16%
- (C) 19%
- (D) 21%
- (E) 23%

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14. For a universal life insurance policy with a death benefit of 150,000, you are given:

(i)

Policy Year	Monthly Premium	Percent of Premium Charge	Monthly Cost of Insurance Rate per 1000	Monthly Expense Charge
1	2000	3.5%	1.00	50

(ii) $i^{(12)} = 0.06$

(iii) The account value at the end of month 11 is 25,000.

Calculate the account value at the end of month 12.

- (A) 26,830
- (B) 26,850
- (C) 26,870
- (D) 26,890
- (E) 26,910

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- 15.** For fully discrete whole life insurance policies of 10,000 issued on 600 lives with independent future lifetimes, each age 62, you are given:
- (i) Mortality follows the Illustrative Life Table.
 - (ii) $i = 0.06$
 - (iii) Expenses of 5% of the first year gross premium are incurred at issue.
 - (iv) Expenses of 5 per policy are incurred at the beginning of each policy year.
 - (v) The gross premium is 102% of the benefit premium.
 - (vi) ${}_0L$ is the aggregate present value of future loss at issue random variable.

Calculate $\Pr({}_0L < 60,000)$, using the normal approximation.

- (A) 0.74
- (B) 0.78
- (C) 0.82
- (D) 0.86
- (E) 0.90

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16. For a fully discrete whole life insurance policy of 2000 on (45), you are given:

- (i) The gross premium is calculated using the equivalence principle.
- (ii) Expenses, payable at the beginning of the year, are:

	% of Premium	Per 1000	Per Policy
First year	25%	1.5	30
Renewal years	5%	0.5	10

- (iii) Mortality follows the Illustrative Life Table.
- (iv) $i = 0.06$

Calculate the expense reserve at the end of policy year 10.

- (A) -2
- (B) -10
- (C) -14
- (D) -19
- (E) -27

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17. You are profit testing a fully discrete whole life insurance of 10,000 on (70). You are given:

- (i) Reserves are benefit reserves based on the Illustrative Life Table and 6% interest.
- (ii) The gross premium is 800.
- (iii) The only expenses are commissions, which are a percentage of gross premiums.
- (iv) There are no withdrawal benefits.
- (v)

Policy Year k	$q_{70+k-1}^{(\text{death})}$	$q_{70+k-1}^{(\text{withdrawal})}$	Commission Rate	Interest Rate
1	0.02	0.20	0.80	0.07
2	0.03	0.04	0.10	0.07

Calculate the expected profit in policy year 2 for a policy in force at the start of year 2.

- (A) 180
- (B) 190
- (C) 200
- (D) 210
- (E) 220

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18. An insurance company sells special fully discrete two-year endowment insurance policies to smokers (S) and non-smokers (NS) age x . You are given:

- (i) The death benefit is 100,000. The maturity benefit is 30,000.
- (ii) The level annual premium for non-smoker policies is determined by the equivalence principle.
- (iii) The annual premium for smoker policies is twice the non-smoker annual premium.
- (iv) $\mu_{x+t}^{\text{NS}} = 0.1, \quad t > 0$
- (v) $q_{x+k}^{\text{S}} = 1.5q_{x+k}^{\text{NS}}$ for $k = 0, 1$
- (vi) $i = 0.08$

Calculate the expected present value of the loss at issue random variable on a smoker policy.

- (A) -30,000
- (B) -29,000
- (C) -28,000
- (D) -27,000
- (E) -26,000

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19. You are given:

(i) The following extract from a mortality table with a one-year select period:

x	$l_{[x]}$	$d_{[x]}$	l_{x+1}	$x+1$
65	1000	40	—	66
66	955	45	—	67

(ii) Deaths are uniformly distributed over each year of age.

(iii) $\overset{\circ}{e}_{[65]} = 15.0$

Calculate $\overset{\circ}{e}_{[66]}$.

- (A) 14.1
- (B) 14.3
- (C) 14.5
- (D) 14.7
- (E) 14.9

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20. Scientists are searching for a vaccine for a disease. You are given:

- (i) 100,000 lives age x are exposed to the disease.
- (ii) Future lifetimes are independent, except that the vaccine, if available, will be given to all at the end of year 1.
- (iii) The probability that the vaccine will be available is 0.2.
- (iv) For each life during year 1, $q_x = 0.02$.
- (v) For each life during year 2, $q_{x+1} = 0.01$ if the vaccine has been given, and $q_{x+1} = 0.02$ if it has not been given.

Calculate the standard deviation of the number of survivors at the end of year 2.

- (A) 100
- (B) 200
- (C) 300
- (D) 400
- (E) 500

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21. You are given:

(i) $\delta_t = 0.06, \quad t \geq 0$

(ii) $\mu_x(t) = 0.01, \quad t \geq 0$

(iii) Y is the present value random variable for a continuous annuity of 1 per year, payable for the lifetime of (x) with 10 years certain.

Calculate $\Pr(Y > E[Y])$.

(A) 0.705

(B) 0.710

(C) 0.715

(D) 0.720

(E) 0.725

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22. For a whole life insurance of 10,000 on (x) , you are given:

- (i) Death benefits are payable at the end of the year of death.
- (ii) A premium of 30 is payable at the start of each month.
- (iii) Commissions are 5% of each premium.
- (iv) Expenses of 100 are payable at the start of each year.
- (v) $i = 0.05$
- (vi) $1000A_{x+10} = 400$
- (vii) ${}_{10}V$ is the gross premium reserve at the end of year 10 for this insurance.

Calculate ${}_{10}V$ using the two-term Woolhouse formula for annuities.

- (A) 950
- (B) 980
- (C) 1010
- (D) 1110
- (E) 1140

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23. For an increasing two-year term insurance on (x) , you are given:

- (i) The death benefit during year k is $2000k$, $k = 1, 2$.
- (ii) Death benefits are payable at the end of the year of death.
- (iii) $q_{x+k-1} = 0.02k$, $k = 1, 2$
- (iv) The following information about zero coupon bonds of 100 at $t = 0$:

Maturity (in years)	Price
1	97.00
2	92.00

- (v) Z is the present value random variable for this insurance.

Calculate $\text{Var}(Z)$.

- (A) 569,600
- (B) 570,600
- (C) 571,600
- (D) 572,600
- (E) 573,600

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- 24.** For a fully discrete whole life insurance, you are given:
- (i) First year expenses are 10% of the gross premium and 5 per policy.
 - (ii) Renewal expenses are 3% of the gross premium and 2 per policy.
 - (iii) Expenses are incurred at the start of each policy year.
 - (iv) There are no deaths or withdrawals in the first two policy years.
 - (v) $i = 0.05$
 - (vi) The asset share at time 0 is 0. The asset share at the end of the second policy year is 64.11.

Calculate the gross premium.

- (A) 32.7
- (B) 34.2
- (C) 35.7
- (D) 37.2
- (E) 38.7

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25. For a fully discrete whole life insurance on (60), you are given:

- (i) Mortality follows the Illustrative Life Table
- (ii) $i = 0.06$
- (iii) The expected company expenses, payable at the beginning of the year, are:
 - 50 in the first year
 - 10 in years 2 through 10
 - 5 in years 11 through 20
 - 0 after year 20

Calculate the level annual amount that is actuarially equivalent to the expected company expenses.

- (A) 8.5
- (B) 11.5
- (C) 12.0
- (D) 13.5
- (E) 15.0

****END OF EXAMINATION****

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