Long-Term Actuarial Mathematics

Sample Multiple Choice Questions

November 4, 2019

There are 237 sample multiple choice questions in this Study Note for the Long-Term Actuarial Mathematics exam. The questions are sorted by the Society of Actuaries' recommended resources for this exam. All question numbers follow the format of X.Y. where X identifies the source and Y is the question number from that source. If the X is a number, then it refers to the chapter of *Actuarial Mathematics for Life Contingent Risks, 2nd Edition.* If the X is LM then it refers to Chapter 12 of *Loss Models, From Data to Decisions, 5th Edition* which is Study Note LTAM-22-18. If the X is S# where the # is a number, then these questions refer to chapter # of the Supplemental Note on Long-term Actuarial Mathematics which is Study Note LTAM-21-18.

Many of these questions are questions that have previously appeared on MLC exams from 2012 through 2017. These are identified by a parenthetical expression at the end of such questions. Questions that have been modified have been modified to:

- Replace the Illustrative Life Table (ILT) which was used on the MLC exam with the Standard Ultimate Life Table (SULT) which will be used with the LTAM exam. All problems that previously used the ILT have been converted to the SULT.

- Change language to reflect the current terms used on the LTAM exam. For example, the current term used is "net premium" where on the earlier MLC exams, the term used was "benefit premium." Where benefit premium appeared in old exam questions, it has been replaced by net premium.

Additionally, questions from previous MLC exams from 2012 to 2017 which covered material that is no longer covered by the Long-Term Actuarial Mathematics exam have been eliminated.

The student should note that multiple choice questions from MLC exams in 2012 and 2013 which are included in these sample questions were intended to average six minutes each. For the multiple choice questions for the MLC exam in 2014 and later were intended to average five minutes each. The multiple choice questions on the Long-Term Actuarial Mathematics exam are intended to average five minutes each. Therefore, the questions based on the 2012 and 2013 MLC exams may be slightly longer that the student will encounter on the Long-Term Actuarial Mathematics exam. That being said, these questions are representative of the types of questions that might be asked of candidates sitting for the Long-Term Actuarial Mathematics exam. These questions are intended to represent the depth of understanding required of candidates. The distribution of questions by topic is not intended to represent the distribution of questions on future exams.

Finally, there are new sample multiple choice questions which primarily cover the material that has been added to the Long-Term Actuarial Mathematics exam.

Versions:

July 2, 2018	Original Set of Questions Published
July 24, 2018	Correction to question 6.25
August 27, 2018	Correction to question LM.3
September 17, 2018	Added 72 questions from the 2016 and 2017 multiple choice MLC exams.
October 13, 2018	Correction to questions 4.21, 6.32 and 6.39.
February 6, 2019	Questions 4.5, 5.3, 5.5, and 5.8 were previously misclassified so they were renumbered to move them to the correct chapter.
July 31, 2019	Questions 6.6 and 6.17 were previously misclassified so they were renumbered to move them to the correct chapter.
November 4, 2019	Correction to the solution for question 2.1.

1.1 Which of the following is not true with regard to underwriting?

(A) Life insurance policies are typically underwritten to prevent adverse selection.

(B) The distribution method affects the level of underwriting.

(C) Single premium immediate annuities are typically underwritten to prevent adverse selection.

(D) Underwriting may result in an insured life being classified as a rated life due to the insured's occupation or hobby.

(E) A pure endowment does not need to be underwritten to prevent adverse selection.

1.2. Over the last 30 years, life insurance products and the management of the associated risks have radically changed and become more complex.

Which of the following is not a reason for this change?

(A) More sophisticated policyholders.

(B) More competition among life insurance companies.

(C) More computational power.

(D) More complex risk management techniques.

(E) Separation of the savings elements and the protection elements of life insurance products.

2.1. You are given:

(i) $S_0(t) = \left(1 - \frac{t}{\omega}\right)^{\frac{1}{4}}$, for $0 \le t \le \omega$

(ii) $\mu_{65} = \frac{1}{180}$

Calculate e_{106}, the curtate expectation of life at age 106.

(A) 2.2

(B) 2.5

(C) 2.7

(D) 3.0

(E) 3.2

[This was Question 3 on the Fall 2012 Multiple Choice exam.]

2.2 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

[This was Question 20 on the Spring 2013 Multiple Choice exam.]

2.3. You are given that mortality follows Gompertz Law with B = 0.00027 and c = 1.1.

Calculate $f_{50}(10)$.

(A) 0.048

(B) 0.050

(C) 0.052

(D) 0.054

(E) 0.056

2.4. You are given ${}_tq_0 = \dfrac{t^2}{10,000}$ for 0 < t < 100.

Calculate $\overset{\circ}{e}_{75:\overline{10|}}$.

(A) 6.6

(B) 7.0

(C) 7.4

(D) 7.8

(E) 8.2

2.5. You are given the following:

(i) $e_{40:\overline{20}|} = 18$

(ii) $e_{60} = 25$

(iii) ${}_{20}q_{40} = 0.2$

(iv) $q_{40} = 0.003$

Calculate e_{41} .

(A) 36.1

(B) 37.1

(C) 38.1

(D) 39.1

(E) 40.1

2.6. You are given the survival function:

$$S_0(x) = \left(1 - \frac{x}{60}\right)^{\frac{1}{3}}, \quad 0 \le x \le 60.$$

Calculate $1000\mu_{35}$.

(A) 5.6

(B) 6.7

(C) 13.3

(D) 16.7

(E) 20.1

[This was Question 2 on the Spring 2016 Multiple Choice exam.]

2.7. You are given the following survival function of a newborn:

$$S_0(x) = \begin{cases} 1 - \dfrac{x}{250}, & 0 \le x < 40 \\ 1 - \left(\dfrac{x}{100}\right)^2, & 40 \le x \le 100 \end{cases}$$

Calculate the probability that (30) dies within the next 20 years.

(A) 0.13

(B) 0.15

(C) 0.17

(D) 0.19

(E) 0.21

[This was Question 2 on the Fall 2016 Multiple Choice exam.]

2.8. In a population initially consisting of 75% females and 25% males, you are given:

(i) For a female, the force of mortality is constant and equals μ.

(ii) For a male, the force of mortality is constant and equals 1.5μ.

(iii) At the end of 20 years, the population consists of 85% females and 15% males.

Calculate the probability that a female survives one year.

(A) 0.89

(B) 0.92

(C) 0.94

(D) 0.96

(E) 0.99

[This was Question 3 on the Fall 2016 Multiple Choice exam.]

3.1. You are given:

(i) An excerpt from a select and ultimate life table with a select period of 3 years:

x	$l_{[x]}$	$l_{[x]+1}$	$l_{[x]+2}$	l_{x+3}	$x+3$
60	80,000	79,000	77,000	74,000	63
61	78,000	76,000	73,000	70,000	64
62	75,000	72,000	69,000	67,000	65
63	71,000	68,000	66,000	65,000	66

(ii) Deaths follow a constant force of mortality over each year of age.

Calculate $1000\ {}_{2|3}q_{[60]+0.75}$.

(A) 104

(B) 117

(C) 122

(D) 135

(E) 142

[This was Question 2 on the Fall 2012 Multiple Choice exam.]

3.2. 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

[This was Question 19 on the Spring 2013 Multiple Choice exam.]

3.3. You are given:

(i) An excerpt from a select and ultimate life table with a select period of 2 years:

x	$l_{[x]}$	$l_{[x]+1}$	l_{x+2}	$x+2$
50	99,000	96,000	93,000	52
51	97,000	93,000	89,000	53
52	93,000	88,000	83,000	54
53	90,000	84,000	78,000	55

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

Calculate $10,000\ {}_{2.2}q_{[51]+0.5}$.

(A) 705

(B) 709

(C) 713

(D) 1070

(E) 1074

[This was Question 3 on the Fall 2013 Multiple Choice exam.]

3.4. The SULT Club has 4000 members all age 25 with independent future lifetimes. The mortality for each member follows the Standard Ultimate Life Table.

Calculate the largest integer *N,* using the normal approximation, such that the probability that there are at least *N* survivors at age 95 is at least 90%.

(A) 800

(B) 815

(C) 830

(D) 845

(E) 860

[This is a modified version of Question 24 on the Fall 2013 Multiple Choice exam.]

3.5. You are given:

(i)

x	l_x
60	99,999
61	88,888
62	77,777
63	66,666
64	55,555
65	44,444
66	33,333
67	22,222

(ii) $a = {}_{3.4|2.5}q_{60}$ assuming a uniform distribution of deaths over each year of age.

(iii) $b = {}_{3.4|2.5}q_{60}$ assuming a constant force of mortality over each year of age.

Calculate $100,000(a-b)$.

(A) -24

(B) 9

(C) 42

(D) 73

(E) 106

[This was Question 25 on the Fall 2013 Multiple Choice exam.]

3.6. You are given the following extract from a table with a 3-year select period:

(i)

x	$q_{[x]}$	$q_{[x]+1}$	$q_{[x]+2}$	q_{x+3}	$x+3$
60	0.09	0.11	0.13	0.15	63
61	0.10	0.12	0.14	0.16	64
62	0.11	0.13	0.15	0.17	65
63	0.12	0.14	0.16	0.18	66
64	0.13	0.15	0.17	0.19	67

(ii) $e_{64} = 5.10$

Calculate $e_{[61]}$.

(A) 5.30

(B) 5.39

(C) 5.68

(D) 5.85

(E) 6.00

[This was Question 2 on the Spring 2014 Multiple Choice exam.]

3.7. For a mortality table with a select period of two years, you are given:

(i)

x	$q_{[x]}$	$q_{[x]+1}$	q_{x+2}	$x+2$
50	0.0050	0.0063	0.0080	52
51	0.0060	0.0073	0.0090	53
52	0.0070	0.0083	0.0100	54
53	0.0080	0.0093	0.0110	55

(ii) The force of mortality is constant between integral ages.

Calculate $1000\,{}_{2.5}q_{[50]+0.4}$.

(A) 15.2

(B) 16.4

(C) 17.7

(D) 19.0

(E) 20.2

[This was Question 20 on the Fall 2014 Multiple Choice exam.]

3.8. A club is established with 2000 members, 1000 of exact age 35 and 1000 of exact age 45.

You are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) Future lifetimes are independent.

(iii) *N* is the random variable for the number of members still alive 40 years after the club is established.

Using the normal approximation, without the continuity correction, calculate the smallest *n* such that $\Pr(N \geq n) \leq 0.05$.

(A) 1500

(B) 1505

(C) 1510

(D) 1515

(E) 1520

[This is a modified version of Question 1 on the Spring 2015 Multiple Choice exam.]

3.9. A father-son club has 4000 members, 2000 of which are age 20 and the other 2000 are age 45. In 25 years, the members of the club intend to hold a reunion.

You are given:

(i) All lives have independent future lifetimes.

(ii) Mortality follows the Standard Ultimate Life Table.

Using the normal approximation, without the continuity correction, calculate the 99th percentile of the number of surviving members at the time of the reunion.

(A) 3810

(B) 3820

(C) 3830

(D) 3840

(E) 3850

[This is a modified version of Question 1 on the Fall 2015 Multiple Choice exam.]

3.10. A group of 100 people start a Scissor Usage Support Group. The rate at which members enter and leave the group is dependent on whether they are right-handed or left-handed.

You are given the following:

(i) The initial membership is made up of 75% left-handed members (L) and 25% right-handed members (R).

(ii) After the group initially forms, 35 new (L) and 15 new (R) join the group at the start of each subsequent year.

(iii) Members leave the group only at the end of each year.

(iv) $q^L = 0.25$ for all years.

(v) $q^R = 0.50$ for all years.

Calculate the proportion of the Scissor Usage Support Group's expected membership that is left-handed at the start of the group's 6th year, before any new members join for that year.

(A) 0.76

(B) 0.81

(C) 0.86

(D) 0.91

(E) 0.96

[This was Question 2 on the Fall 2015 Multiple Choice exam.]

3.11. For the country of Bienna, you are given:

(i) Bienna publishes mortality rates in biennial form, that is, mortality rates are of the form:
$_2q_{2x}$, for $x = 0,1,2,...$

(ii) Deaths are assumed to be uniformly distributed between ages $2x$ and $2x+2$, for $x = 0,1,2,...$

(iii) $_2q_{50} = 0.02$

(iv) $_2q_{52} = 0.04$

Calculate the probability that (50) dies during the next 2.5 years.

(A) 0.02

(B) 0.03

(C) 0.04

(D) 0.05

(E) 0.06

[This was Question 1 on the Fall 2016 Multiple Choice exam.]

3.12. Barry and Steve are both age 61. Barry has just purchased a whole life insurance policy. Steve purchased a whole life insurance policy one year ago.

Both Barry and Steve are subject to the following 3-year select and ultimate table:

x	$\ell_{[x]}$	$\ell_{[x]+1}$	$\ell_{[x]+2}$	ℓ_{x+3}	$x+3$
60	10,000	9,600	8,640	7,771	63
61	8,654	8,135	6,996	5,737	64
62	7,119	6,549	5,501	4,016	65
63	5,760	4,954	3,765	2,410	66

The force of mortality is constant over each year of age.

Calculate the difference in the probability of survival to age 64.5 between Barry and Steve.

(A) 0.035

(B) 0.045

(C) 0.055

(D) 0.065

(E) 0.075

[This was Question 2 on the Spring 2017 Multiple Choice exam.]

3.13. A life is subject to the following 3-year select and ultimate table:

$[x]$	$\ell_{[x]}$	$\ell_{[x]+1}$	$\ell_{[x]+2}$	ℓ_{x+3}	$x+3$
55	10,000	9,493	8,533	7,664	58
56	8,547	8,028	6,889	5,630	59
57	7,011	6,443	5,395	3,904	60
58	5,853	4,846	3,548	2,210	61

You are also given:

(i) $e_{60} = 1$

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

Calculate $\mathring{e}_{[58]+2}$.

(A) 1.5

(B) 1.6

(C) 1.7

(D) 1.8

(E) 1.9

[This was Question 1 on the Fall 2017 Multiple Choice exam.]

4.1. For a special whole life insurance policy issued on (40), you are given:

(i) Death benefits are payable at the end of the year of death.

(ii) The amount of benefit is 2 if death occurs within the first 20 years and is 1 thereafter.

(iii) *Z* is the present value random variable for the payments under this insurance.

(iv) $i = 0.03$

(v)

x	A_x	${}_{20}E_x$
40	0.36987	0.51276
60	0.62567	0.17878

(vi) $E\left[Z^2\right] = 0.24954$

Calculate the standard deviation of *Z*.

(A) 0.27

(B) 0.32

(C) 0.37

(D) 0.42

(E) 0.47

[This was Question 14 on the Fall 2012 Multiple Choice exam.]

4.2. For a special 2-year term insurance policy on (x), you are given:

(i) Death benefits are payable at the end of the half-year of death.

(ii) The amount of the death benefit is 300,000 for the first half-year and increases by 30,000 per half-year thereafter.

(iii) $q_x = 0.16$ and $q_{x+1} = 0.23$

(iv) $i^{(2)} = 0.18$

(v) Deaths are assumed to follow a constant force of mortality between integral ages.

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

Calculate $\Pr(Z > 277{,}000)$.

(A) 0.08

(B) 0.11

(C) 0.14

(D) 0.18

(E) 0.21

[This was Question 15 on the Fall 2012 Multiple Choice exam.]

4.3. 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

[This was Question 7 on the Spring 2013 Multiple Choice exam.]

4.4 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 $b_t = 1 + 0.2t, \quad t \geq 0$

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

(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 Var(*Z*).

(A) 0.036

(B) 0.038

(C) 0.040

(D) 0.042

(E) 0.044

[This was Question 8 on the Spring 2013 Multiple Choice exam.]

4.5. Question 4.5 was misclassified and therefore was moved to Question 8.26.

4.6. For a 3-year term insurance of 1000 on (70), you are given:

(i) q_{70+k}^{SULT} is the mortality rate from the Standard Ultimate Life Table, for $k = 0,1,2$.

(ii) q_{70+k} is the mortality rate used to price this insurance, for $k = 0,1,2$.

(iii) $q_{70+k} = (0.95)^k \, q_{70+k}^{SULT}$, for $k = 0,1,2$.

(iv) $i = 0.05$

Calculate the single net premium.

(A) 29.05

(B) 29.85

(C) 30.65

(D) 31.45

(E) 32.25

[This is a modified version of Question 13 on the Fall 2013 Multiple Choice exam.]

4.7. You are given the following information from a life table:

(i)

x	l_x	d_x	p_x	q_x
95	–	–	–	0.40
96	–	–	0.20	–
97	–	72	–	1.00

(ii) $l_{90} = 1000$ and $l_{93} = 825$

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

Calculate the probability that (90) dies between ages 93 and 95.5.

(A) 0.195

(B) 0.220

(C) 0.345

(D) 0.465

(E) 0.668

[This was Question 1 on the Spring 2014 Multiple Choice exam.]

4.8. For a whole life insurance of 1000 on (50), you are given:

(i) The death benefit is payable at the end of the year of death.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.04$ in the first year, and $i = 0.05$ in subsequent years.

Calculate the actuarial present value of this insurance.

(A) 187

(B) 189

(C) 191

(D) 193

(E) 195

[This is a modified version of Question 5 on the Spring 2014 Multiple Choice exam.]

4.9. You are given:

(i) $A_{35:\overline{15}|} = 0.39$

(ii) $A^{\;1}_{35:\overline{15}|} = 0.25$

(iii) $A_{35} = 0.32$

Calculate A_{50}.

(A) 0.35

(B) 0.40

(C) 0.45

(D) 0.50

(E) 0.55

[This was Question 4 on the Fall 2014 Multiple Choice exam.]

4.10. The present value random variable for an insurance policy on (*x*) is expressed as:

$$Z = \begin{cases} 0, & \text{if } T_x \leq 10 \\ v^{T_x}, & \text{if } 10 < T_x \leq 20 \\ 2v^{T_x}, & \text{if } 20 < T_x \leq 30 \\ 0, & \text{thereafter} \end{cases}$$

Which of the following is a correct expression for $E[Z]$?

(A) $_{10|}\bar{A}_x + {}_{20|}\bar{A}_x - {}_{30|}\bar{A}_x$

(B) $\bar{A}_x + {}_{20}E_x\,\bar{A}_{x+20} - 2\,{}_{30}E_x\,\bar{A}_{x+30}$

(C) $_{10}E_x\,\bar{A}_x + {}_{20}E_x\,\bar{A}_{x+20} - 2\,{}_{30}E_x\,\bar{A}_{x+30}$

(D) $_{10}E_x\,\bar{A}_{x+10} + {}_{20}E_x\,\bar{A}_{x+20} - 2\,{}_{30}E_x\,\bar{A}_{x+30}$

(E) $_{10}E_x\left[\bar{A}_{x+10} + {}_{10}E_{x+10}\,\bar{A}_{x+20} - {}_{10}E_{x+20}\,\bar{A}_{x+30}\right]$

[This was Question 4 on the Spring 2015 Multiple Choice exam.]

4.11. You are given:

(i) Z_1 is the present value random variable for an *n*-year term insurance of 1000 issued to (*x*).

(ii) Z_2 is the present value random variable for an *n*-year endowment insurance of 1000 issued to (*x*).

(iii) For both Z_1 and Z_2 the death benefit is payable at the end of the year of death.

(iv) $E[Z_1] = 528$

(v) $Var(Z_2) = 15{,}000$

(vi) $A_{\stackrel{1}{x:\overline{n|}}} = 0.209$

(vii) ${}^2A_{\stackrel{1}{x:\overline{n|}}} = 0.136$

Calculate $Var(Z_1)$.

(A) 143,400

(B) 177,500

(C) 211,200

(D) 245,300

(E) 279,300

[This was Question 5 on the Spring 2015 Multiple Choice exam.]

4.12. For three fully discrete insurance products on the same (*x*), you are given:

(i) Z_1 is the present value random variable for a 20-year term insurance of 50.

(ii) Z_2 is the present value random variable for a 20-year deferred whole life insurance of 100.

(iii) Z_3 is the present value random variable for a whole life insurance of 100.

(iv) $E\left[Z_1\right]=1.65$ and $E\left[Z_2\right]=10.75$.

(v) $Var\left(Z_1\right)=46.75$ and $Var\left(Z_2\right)=50.78$.

Calculate $Var\left(Z_3\right)$.

(A) 62

(B) 109

(C) 167

(D) 202

(E) 238

[This was Question 4 on the Fall 2015 Multiple Choice exam.]

4.13. For a 2-year deferred, 2-year term insurance of 2000 on [65], you are given:

(i) The following select and ultimate mortality table with a 3-year select period:

x	$q_{[x]}$	$q_{[x]+1}$	$q_{[x]+2}$	q_{x+3}	$x+3$
65	0.08	0.10	0.12	0.14	68
66	0.09	0.11	0.13	0.15	69
67	0.10	0.12	0.14	0.16	70
68	0.11	0.13	0.15	0.17	71
69	0.12	0.14	0.16	0.18	72

(ii) $i = 0.04$

(iii) The death benefit is payable at the end of the year of death.

Calculate the actuarial present value of this insurance.

(A) 260

(B) 290

(C) 350

(D) 370

(E) 410

[This was Question 9 on the Fall 2015 Multiple Choice exam.]

4.14. A fund is established for the benefit of 400 workers all age 60 with independent future lifetimes. When they reach age 85, the fund will be dissolved and distributed to the survivors.

The fund will earn interest at a rate of 5% per year.

The initial fund balance, F, is determined so that the probability that the fund will pay at least 5000 to each survivor is 86%, using the normal approximation.

Mortality follows the Standard Ultimate Life Table.

Calculate F.

(A) 350,000

(B) 360,000

(C) 370,000

(D) 380,000

(E) 390,000

[This is a modified version of Question 3 on the Spring 2016 Multiple Choice exam.]

4.15. For a special whole life insurance on (*x*), you are given:

(i) Death benefits are payable at the moment of death.

(ii) The death benefit at time *t* is $b_t = e^{0.02t}$, for $t \geq 0$.

(iii) $\mu_{x+t} = 0.04$, for $t \geq 0$

(iv) $\delta = 0.06$

(v) *Z* is the present value at issue random variable for this insurance.

Calculate $Var(Z)$.

(A) 0.020

(B) 0.036

(C) 0.052

(D) 0.068

(E) 0.083

[This was Question 4 on the Fall 2016 Multiple Choice exam.]

4.16. You are given the following extract of ultimate mortality rates from a two-year select and ultimate mortality table:

x	q_x
50	0.045
51	0.050
52	0.055
53	0.060

The select mortality rates satisfy the following:

(i) $q_{[x]} = 0.7q_x$

(ii) $q_{[x]+1} = 0.8q_{x+1}$

You are also given that $i = 0.04$.

Calculate $A^{\,1}_{[50]:\overline{3|}}$.

(A) 0.08

(B) 0.09

(C) 0.10

(D) 0.11

(E) 0.12

[This was Question 5 on the Fall 2016 Multiple Choice exam.]

4.17. For a special fully discrete whole life policy on (48), you are given:

(i) The policy pays 5000 if the insured dies before his median curtate future lifetime at issue and 10,000 if he dies after his median curtate future lifetime at issue.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate the actuarial present value of benefits for this policy.

(A) 1130

(B) 1160

(C) 1190

(D) 1220

(E) 1250

[This is a modified version of Question 6 on the Fall 2016 Multiple Choice exam.]

4.18. You are given that *T*, the time to first failure of an industrial robot, has a density $f(t)$ given by

$$f(t) = \begin{cases} 0.1, & 0 \le t < 2 \\ 0.4t^{-2}, & 2 \le t < 10 \end{cases}$$

with $f(t)$ undetermined on $[10, \infty)$.

Consider a supplemental warranty on this robot which pays 100,000 at the time *T* of its first failure if $2 \le T \le 10$, with no benefits payable otherwise.

You are also given that $\delta = 5\%$.

Calculate the 90th percentile of the present value of the future benefits under this warranty.

(A) 82,000

(B) 84,000

(C) 87,000

(D) 91,000

(E) 95,000

[This was Question 5 on the Spring 2017 Multiple Choice exam.]

4.19. Ming, age 80, purchases a whole life insurance policy of 100,000.

You are given:

(i) The policy is priced with a select period of one year.

(ii) The select mortality rate equals 80% of the mortality rate from the Standard Ultimate Life Table.

(iii) Ultimate mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate the actuarial present value of the death benefits for this insurance.

(A) 58,950

(B) 59,050

(C) 59,150

(D) 59,250

(E) 59,350

[This is a modified version of Question 5 on the Fall 2017 Multiple Choice exam.]

4.20. For a 25-year pure endowment of 1 on (x), you are given:

(i) Z is the present value random variable at issue of the benefit payment.

(ii) $Var(Z) = 0.10E[Z]$

(iii) ${}_{25}p_x = 0.57$

Calculate the annual effective interest rate.

(A) 5.8%

(B) 6.0%

(C) 6.2%

(D) 6.4%

(E) 6.6%

[This was Question 6 on the Fall 2017 Multiple Choice exam.]

4.21. For a 30-year term life insurance of 100,000 on (45), you are given:

(i) The death benefit is payable at the moment of death.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $\delta = 0.05$

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

Calculate the 95th percentile of the present value of benefits random variable for this insurance.

(A) 30,200

(B) 31,200

(C) 35,200

(D) 36,200

(E) 37,200

[This is a modified version of Question 11 on the Fall 2017 Multiple Choice exam.]

4.22. You are given:

(i) Mortality follows the Standard Ultimate Life Table.

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

(iii) $i = 0.05$

Calculate $\dfrac{d}{dt}(\overline{Ia})_{40:\overline{t|}}$ at $t = 10.5$.

(A) 5.8

(B) 6.0

(C) 6.2

(D) 6.4

(E) 6.6

[This is a modified version of Question 19 on the Fall 2017 Multiple Choice exam.]

5.1. 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 $\Pr(Y > \mathrm{E}[Y])$.

(A) 0.705

(B) 0.710

(C) 0.715

(D) 0.720

(E) 0.725

[This was Question 21 on the Spring 2013 Multiple Choice exam.]

5.2. You are given:

(i) $A_x = 0.30$

(ii) $A_{x+n} = 0.40$

(iii) $A_{\substack{1\\x:\overline{n}|}} = 0.35$

(iv) $i = 0.05$

Calculate $a_{x:\overline{n}|}$.

(A) 9.3

(B) 9.6

(C) 9.8

(D) 10.0

(E) 10.3

[This was Question 1 on the Fall 2013 Multiple Choice exam.]

5.3. Question 5.3 was misclassified and therefore was moved to Question 9.14.

5.4. Russell, age 40, wins the SOA lottery. He will receive both:

- A deferred life annuity of *K* per year, payable continuously, starting at age $40+\mathring{e}_{40}$ and
- An annuity certain of *K* per year, payable continuously, for $\mathring{e}_{40}$ years

You are given:

(i) $\mu = 0.02$

(ii) $\delta = 0.01$

(iii) The actuarial present value of the payments is 10,000.

Calculate *K*.

(A) 214

(B) 216

(C) 218

(D) 220

(E) 222

[This was Question 5 on the Fall 2013 Multiple Choice exam.]

5.5. Question 5.5 was misclassified and therefore was moved to Question 6.51.

5.6. For a group of 100 lives age *x* with independent future lifetimes, you are given:

(i) Each life is to be paid 1 at the beginning of each year, if alive.

(ii) $A_x = 0.45$

(iii) ${}^2A_x = 0.22$

(iv) $i = 0.05$

Y is the present value random variable of the aggregate payments.

Using the normal approximation to *Y*, calculate the initial size of the fund needed in order to be 95% certain of being able to make the payments for these life annuities.

(A) 1170

(B) 1180

(C) 1190

(D) 1200

(E) 1210

[This was Question 6 on the Spring 2014 Multiple Choice exam.]

5.7. You are given:

(i) $A_{35} = 0.188$

(ii) $A_{65} = 0.498$

(iii) ${}_{30}p_{35} = 0.883$

(iv) $i = 0.04$

Calculate $1000\,\ddot{a}^{(2)}_{35:\overline{30|}}$ using the two-term Woolhouse approximation.

(A) 17,060

(B) 17,310

(C) 17,380

(D) 17,490

(E) 17,530

[This was Question 7 on the Spring 2015 Multiple Choice exam.]

5.8. Question 5.8 was misclassified and therefore was moved to Question 9.15.

5.9. For a select and ultimate mortality model with a one-year select period, you are given:

(i) $p_{[x]} = (1+k)\,p_x$, for some constant k

(ii) $\ddot{a}_{x:\overline{n}|} = 21.854$

(iii) $\ddot{a}_{[x]:\overline{n}|} = 22.167$

Calculate k.

(A) 0.005

(B) 0.010

(C) 0.015

(D) 0.020

(E) 0.025

[This was Question 5 on the Spring 2016 Multiple Choice exam.]

5.10. For an annual life annuity-due of 1 with a 5-year certain period on (55), you are given:

(i) Mortality follows the Standard Ultimate Life Table

(ii) $i = 0.05$

Calculate the probability that the sum of the undiscounted payments actually made under this annuity will exceed the expected present value, at issue, of the annuity.

(A) 0.88

(B) 0.90

(C) 0.92

(D) 0.94

(E) 0.96

[This is a modified version of Question 6 on the Spring 2017 Multiple Choice exam.]

5.11. For an annuity-due that pays 100 at the beginning of each year that (45) is alive, you are given:

(i) Mortality for standard lives follows the Standard Ultimate Life Table.

(ii) The force of mortality for standard lives age $45+t$ is represented as μ_{45+t}^{SULT}.

(iii) The force of mortality for substandard lives age $45+t$, μ_{45+t}^{S}, is defined as:

$$\mu_{45+t}^{S} = \begin{cases} \mu_{45+t}^{SULT} + 0.05, & \text{for } 0 \le t < 1 \\ \mu_{45+t}^{SULT}, & \text{for } t \ge 1 \end{cases}$$

(iv) $i = 0.05$

Calculate the actuarial present value of this annuity for a substandard life age 45.

(A) 1700

(B) 1710

(C) 1720

(D) 1730

(E) 1740

[This is a modified version of Question 4 on the Fall 2017 Multiple Choice exam.]

6.1. You are given the following information about a special fully discrete 2-payment, 2-year term insurance on (80):

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.03$

(iii) The death benefit is 1000 plus a return of all premiums paid without interest.

(iv) Level premiums are calculated using the equivalence principle.

Calculate the net premium for this special insurance.

(A) 32

(B) 33

(C) 34

(D) 35

(E) 36

[This is a modified version of Question 22 on the Fall 2012 Multiple Choice exam.]

6.2. For a fully discrete 10-year term life insurance policy on (x), you are given:

(i) Death benefits are 100,000 plus the return of all gross premiums paid without interest.

(ii) Expenses are 50% of the first year's gross premium, 5% of renewal gross premiums and 200 per policy expenses each year.

(iii) Expenses are payable at the beginning of the year.

(iv) $A^{1}_{x:\overline{10}|} = 0.17094$

(v) $(IA)^{1}_{x:\overline{10}|} = 0.96728$

(vi) $\ddot{a}_{x:\overline{10}|} = 6.8865$

Calculate the gross premium using the equivalence principle.

(A) 3200

(B) 3300

(C) 3400

(D) 3500

(E) 3600

[This was Question 25 on the Fall 2012 Multiple Choice exam.]

6.3. Stuart, now age 65, purchased a 20-year deferred whole life annuity-due of 1 per year at age 45. You are given:

(i) Equal annual premiums, determined using the equivalence principle, were paid at the beginning of each year during the deferral period.

(ii) Mortality at ages 65 and older follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) *Y* is the present value random variable at age 65 for Stuart's annuity benefits.

Calculate the probability that *Y* is less than the actuarial accumulated value of Stuart's premiums.

(A) 0.35

(B) 0.37

(C) 0.39

(D) 0.41

(E) 0.43

[This is a modified version of Question 20 on the Fall 2012 Multiple Choice exam.]

6.4. For whole life annuities-due of 15 per month on each of 200 lives age 62 with independent future lifetimes, you are given:

(i) $i = 0.06$

(ii) $A_{62}^{(12)} = 0.4075$ and ${}^{2}A_{62}^{(12)} = 0.2105$

(iii) π is the single premium to be paid by each of the 200 lives.

(iv) *S* is the present value random variable at time 0 of total payments made to the 200 lives.

Using the normal approximation, calculate π such that $\Pr(200\pi > S) = 0.90$.

(A) 1850

(B) 1860

(C) 1870

(D) 1880

(E) 1890

[This was Question 19 on the Fall 2012 Multiple Choice exam.]

6.5. For a fully discrete whole life insurance of 1000 on (30), you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) The premium is the net 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) 21

(B) 25

(C) 29

(D) 33

(E) 37

[This is a modified version of Question 1 on the Spring 2013 Multiple Choice exam.]

6.6. Question 6.6 was misclassified and therefore was moved to Question 8.27.

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

(i) The only death benefit is the return of annual net premiums accumulated with interest at 5% to the end of the year of death.

(ii) The endowment benefit is 100,000.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate the annual net premium.

(A) 2680

(B) 2780

(C) 2880

(D) 2980

(E) 3080

[This is a modified version of Question 3 on the Spring 2013 Multiple Choice exam.]

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

(i) Mortality follows the Standard Ultimate Life Table

(ii) $i = 0.05$

(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) 7.5

(B) 9.5

(C) 11.5

(D) 13.5

(E) 15.5

[This was Question 2 on the Spring 2013 Multiple Choice exam.]

6.9. For a fully discrete 20-year term insurance of 100,000 on (50), you are given:

(i) Gross premiums are payable for 10 years.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) Expenses are incurred at the beginning of each year as follows:

	Year 1	Years 2-10	Years 11-20
Commission as % of premium	40%	10%	Not applicable
Premium taxes as % of premium	2%	2%	Not applicable
Maintenance expenses	75	25	25

(v) Gross premiums are calculated using the equivalence principle.

Calculate the gross premium for this insurance.

(A) 617

(B) 627

(C) 637

(D) 647

(E) 657

[This is a modified version of Question 9 on the Fall 2013 Multiple Choice exam.]

6.10. For a fully discrete 3-year term insurance of 1000 on (*x*), you are given:

(i) $p_x = 0.975$

(ii) $i = 0.06$

(iii) The actuarial present value of the death benefit is 152.85.

(iv) The annual net premium is 56.05.

Calculate p_{x+2}.

(A) 0.88

(B) 0.89

(C) 0.90

(D) 0.91

(E) 0.92

[This is a modified version of Question 15 on the Fall 2013 Multiple Choice exam.]

6.11. For fully discrete whole life insurances of 1 issued on lives age 50, the annual net premium, *P*, was calculated using the following:

(i) $q_{50} = 0.0048$

(ii) $i = 0.04$

(iii) $A_{51} = 0.39788$

A particular life has a first year mortality rate 10 times the rate used to calculate *P*. The mortality rates for all other years are the same as the ones used to calculate *P*.

Calculate the expected present value of the loss at issue random variable for this life, based on the premium *P*.

(A) 0.025

(B) 0.033

(C) 0.041

(D) 0.049

(E) 0.057

[This is a modified version of Question 16 on the Fall 2013 Multiple Choice exam.]

6.12. For a fully discrete whole life insurance of 1000 on (x), you are given:

(i) The following expenses are incurred at the beginning of each year:

	Year 1	Years 2+
Percent of premium	75%	10%
Maintenance expenses	10	2

(ii) An additional expense of 20 is paid when the death benefit is paid.

(iii) The gross premium is determined using the equivalence principle.

(iv) $i = 0.06$

(v) $\ddot{a}_x = 12.0$

(vi) ${}^2A_x = 0.14$

Calculate the variance of the loss at issue random variable.

(A) 14,600

(B) 33,100

(C) 51,700

(D) 70,300

(E) 88,900

[This was Question 18 on the Fall 2013 Multiple Choice exam.]

6.13. For a fully discrete whole life insurance of 10,000 on (45), you are given:

(i) Commissions are 80% of the first year premium and 10% of subsequent premiums. There are no other expenses.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) ${}_0L$ denotes the loss at issue random variable.

(v) If $T_{45} = 10.5,$ then ${}_0L = 4953.$

Calculate $\mathrm{E}\left[{}_0L\right].$

(A) -580

(B) -520

(C) -460

(D) -400

(E) -340

[This is a modified version of Question 19 on the Fall 2013 Multiple Choice exam.]

6.14. For a special fully discrete whole life insurance of 100,000 on (40), you are given:

(i) The annual net premium is P for years 1 through 10, $0.5P$ for years 11 through 20, and 0 thereafter.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate P.

(A) 850

(B) 950

(C) 1050

(D) 1150

(E) 1250

[This is a modified version of Question 8 on the Spring 2014 Multiple Choice exam.]

6.15. For a fully discrete whole life insurance of 1000 on (x) with net premiums payable quarterly, you are given:

(i) $i = 0.05$

(ii) $\ddot{a}_x = 3.4611$

(iii) $P^{(W)}$ and $P^{(UDD)}$ are the annualized net premiums calculated using the 2-term Woolhouse (W) and the uniform distribution of deaths (UDD) assumptions, respectively.

Calculate $\dfrac{P^{(UDD)}}{P^{(W)}}$.

(A) 1.000

(B) 1.002

(C) 1.004

(D) 1.006

(E) 1.008

[This is a modified version of Question 9 on the Spring 2014 Multiple Choice exam.]

6.16. For a fully discrete 20-year endowment insurance of 100,000 on (30), you are given:

(i) $d = 0.05$

(ii) Expenses, payable at the beginning of each year, are:

	First Year		Renewal Years	
	Percent of Premium	Per Policy	Percent of Premium	Per Policy
Taxes	4%	0	4%	0
Sales Commission	35%	0	2%	0
Policy Maintenance	0%	250	0%	50

(iii) The net premium is 2143.

Calculate the gross premium using the equivalence principle.

(A) 2410

(B) 2530

(C) 2800

(D) 3130

(E) 3280

[This was Question 10 on the Spring 2014 Multiple Choice exam.]

6.17. Question 6.17 was misclassified and therefore was moved to Question 7.45.

6.18. For a 20-year deferred whole life annuity-due with annual payments of 30,000 on (40), you are given:

(i) The single net premium is refunded without interest at the end of the year of death if death occurs during the deferral period.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate the single net premium for this annuity.

(A) 162,000

(B) 164,000

(C) 165,200

(D) 166,400

(E) 168,800

[This is a modified version of Question 6 on the Fall 2014 Multiple Choice exam.]

6.19. For a fully discrete whole life insurance of 1 on (50), you are given:

(i) Expenses of 0.20 at the start of the first year and 0.01 at the start of each renewal year are incurred.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Gross premiums are determined using the equivalence principle.

Calculate the variance of L_0, the gross loss-at-issue random variable.

(A) 0.023

(B) 0.028

(C) 0.033

(D) 0.038

(E) 0.043

[This is a modified version of Question 7 on the Fall 2014 Multiple Choice exam.]

6.20. For a special fully discrete 3-year term insurance on (75), you are given:

(i) The death benefit during the first two years is the sum of the net premiums paid without interest.

(ii) The death benefit in the third year is 10,000.

(iii)

x	p_x
75	0.90
76	0.88
77	0.85

(iv) $i = 0.04$

Calculate the annual net premium.

(A) 449

(B) 459

(C) 469

(D) 479

(E) 489

[This was Question 8 on the Fall 2014 Multiple Choice exam.]

6.21. For a special fully discrete 15-year endowment insurance on (75), you are given:

(i) The death benefit is 1000.

(ii) The endowment benefit is the sum of the net premiums paid without interest.

(iii) $d = 0.04$

(iv) $A_{75:\overline{15|}} = 0.70$

(v) $A_{75:\overline{15|}}^{\;\;\;\;1} = 0.11$

Calculate the annual net premium.

(A) 80

(B) 90

(C) 100

(D) 110

(E) 120

[This was Question 9 on the Fall 2014 Multiple Choice exam.]

6.22. For a whole life insurance of 100,000 on (45) with premiums payable monthly for a period of 20 years, you are given:

(i) The death benefit is paid immediately upon death.

(ii) Mortality follows the Standard Ultimate Life Table.

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

(iv) $i = 0.05$

Calculate the monthly net premium.

(A) 98

(B) 100

(C) 102

(D) 104

(E) 106

[This is a modified version of Question 10 on the Fall 2014 Multiple Choice exam.]

6.23. For fully discrete 30-payment whole life insurance policies on (x), you are given:

(i) The following expenses payable at the beginning of the year:

	1st Year	Years 2 – 15	Years 16 – 30	Years 31 and after
Per policy	60	30	30	30
Percent of premium	80%	20%	10%	0%

(ii) $\ddot{a}_x = 15.3926$

(iii) $\ddot{a}_{x:\overline{15}|} = 10.1329$

(iv) $\ddot{a}_{x:\overline{30}|} = 14.0145$

(v) Annual gross premiums are calculated using the equivalence principle.

(vi) The annual gross premium is expressed as $kF + h$, where F is the death benefit and k and h are constants for all F.

Calculate *h*.

(A) 30.3

(B) 35.1

(C) 39.9

(D) 44.7

(E) 49.5

[This was Question 11 on the Fall 2014 Multiple Choice exam.]

6.24. For a fully continuous whole life insurance of 1 on (x), you are given:

(i) L is the present value of the loss at issue random variable if the premium rate is determined by the equivalence principle.

(ii) L^* is the present value of the loss at issue random variable if the premium rate is 0.06.

(iii) $\delta = 0.07$

(iv) $\bar{A}_x = 0.30$

(v) $Var(L) = 0.18$

Calculate $Var(L^*)$.

(A) 0.18

(B) 0.21

(C) 0.24

(D) 0.27

(E) 0.30

[This was Question 8 on the Spring 2015 Multiple Choice exam.]

6.25. For a fully discrete 10-year deferred whole life annuity-due of 1000 per month on (55), you are given:

(i) The premium, *G*, will be paid annually at the beginning of each year during the deferral period.

(ii) Expenses are expected to be 300 per year for all years, payable at the beginning of the year.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Using the two-term Woolhouse approximation, the expected loss at issue is -800.

Calculate *G*.

(A) 12,110

(B) 12,220

(C) 12,330

(D) 12,440

(E) 12,550

[This is a modified version of Question 9 on the Spring 2015 Multiple Choice exam.]

6.26. For a special fully discrete whole life insurance policy of 1000 on (90), you are given:

(i) The first year premium is 0.

(ii) *P* is the renewal premium.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

(v) Premiums are calculated using the equivalence principle.

Calculate *P*.

(A) 150

(B) 160

(C) 170

(D) 180

(E) 190

[This is a modified version of Question 10 on the Spring 2015 Multiple Choice exam.]

6.27. For a special fully continuous whole life insurance on (x), you are given:

(i) Premiums and benefits:

	First 20 years	After 20 years
Premium Rate	3*P*	*P*
Benefit	1,000,000	500,000

(ii) $\mu_{x+t} = 0.03, \ t \geq 0$

(iii) $\delta = 0.06$

Calculate *P* using the equivalence principle.

(A) 10,130

(B) 10,190

(C) 10,250

(D) 10,310

(E) 10,370

[This was Question 11 on the Spring 2015 Multiple Choice exam.]

6.28. For a fully discrete 5-payment whole life insurance of 1000 on (40), you are given:

(i) Expenses incurred at the beginning of the first five policy years are as follows:

	Year 1		Years 2-5	
	Percent of premium	Per policy	Percent of premium	Per policy
Sales Commissions	20%	0	5%	0
Policy Maintenance	0%	10	0%	5

(ii) No expenses are incurred after Year 5.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate the gross premium using the equivalence principle.

(A) 31

(B) 36

(C) 41

(D) 46

(E) 51

[This is a modified version of Question 12 on the Spring 2015 Multiple Choice exam.]

6.29. Cathy purchases a fully discrete whole life insurance policy of 100,000 on her 35th birthday.

You are given:

(i) The annual gross premium, calculated using the equivalence principle, is 1770.

(ii) The expenses in policy year 1 are 50% of premium and 200 per policy.

(iii) The expenses in policy years 2 and later are 10% of premium and 50 per policy.

(iv) All expenses are incurred at the beginning of the policy year.

(v) $i = 0.035$

Calculate $\ddot{a}_{35}$.

(A) 20.0

(B) 20.5

(C) 21.0

(D) 21.5

(E) 22.0

[This was Question 7 on the Fall 2015 Multiple Choice exam.]

6.30. For a fully discrete whole life insurance of 100 on (*x*), you are given:

(i) The first year expense is 10% of the gross annual premium.

(ii) Expenses in subsequent years are 5% of the gross annual premium.

(iii) The gross premium calculated using the equivalence principle is 2.338.

(iv) $i = 0.04$

(v) $\ddot{a}_x = 16.50$

(vi) ${}^2A_x = 0.17$

Calculate the variance of the loss at issue random variable.

(A) 900

(B) 1200

(C) 1500

(D) 1800

(E) 2100

[This was Question 8 on the Fall 2015 Multiple Choice exam.]

6.31. For a fully continuous whole life insurance policy of 100,000 on (35), you are given:

(i) The density function of the future lifetime of a newborn:

$$f(t)=\begin{cases}0.01e^{-0.01t}, & 0\le t<70\\ g(t), & t\ge 70\end{cases}$$

(ii) $\delta=0.05$

(iii) $\bar{A}_{70}=0.51791$

Calculate the annual net premium rate for this policy.

(A) 1000

(B) 1110

(C) 1220

(D) 1330

(E) 1440

[This was Question 10 on the Fall 2015 Multiple Choice exam.]

6.32. For a whole life insurance of 100,000 on (x), you are given:

(i) Death benefits are payable at the moment of death.

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

(iii) Premiums are payable monthly.

(iv) $i = 0.05$

(v) $\ddot{a}_x = 9.19$

Calculate the monthly net premium.

(A) 530

(B) 540

(C) 550

(D) 560

(E) 570

[This was Question 11 on the Fall 2015 Multiple Choice exam.]

6.33. An insurance company sells 15-year pure endowments of 10,000 to 500 lives, each age *x*, with independent future lifetimes. The single premium for each pure endowment is determined by the equivalence principle.

You are given:

(i) $i = 0.03$

(ii) $\mu_x(t) = 0.02t, \quad t \geq 0$

(iii) ${}_0L$ is the aggregate loss at issue random variable for these pure endowments.

Using the normal approximation without continuity correction, calculate $\Pr\left({}_0L > 50{,}000\right)$.

(A) 0.08

(B) 0.13

(C) 0.18

(D) 0.23

(E) 0.28

[This was Question 12 on the Fall 2013 Multiple Choice exam.]

6.34. For a fully discrete whole life insurance policy on (61), you are given:

(i) The annual gross premium using the equivalence principle is 500.

(ii) Initial expenses, incurred at policy issue, are 15% of the premium.

(iii) Renewal expenses, incurred at the beginning of each year after the first, are 3% of the premium.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) $i = 0.05$

Calculate the amount of the death benefit.

(A) 23,300

(B) 23,400

(C) 23,500

(D) 23,600

(E) 23,700

[This is a modified version of Question 17 on the Spring 2015 Multiple Choice exam.]

6.35. For a fully discrete whole life insurance policy of 100,000 on (35), you are given:

(i) First year commissions are 19% of the annual gross premium.

(ii) Renewal year commissions are 4% of the annual gross premium.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate the annual gross premium for this policy using the equivalence principle.

(A) 410

(B) 450

(C) 490

(D) 530

(E) 570

[This is a modified version of Question 7 on the Spring 2016 Multiple Choice exam.]

6.36. For a fully continuous 20-year term insurance policy of 100,000 on (50), you are given:

(i) Gross premiums, calculated using the equivalence principle, are payable at an annual rate of 4500.

(ii) Expenses at an annual rate of *R* are payable continuously throughout the life of the policy.

(iii) $\mu_{50+t} = 0.04$, for $t > 0$

(iv) $\delta = 0.08$

Calculate *R*.

(A) 400

(B) 500

(C) 600

(D) 700

(E) 800

[This was Question 8 on the Spring 2016 Multiple Choice exam.]

6.37. For a fully discrete whole life insurance policy of 50,000 on (35), with premiums payable for a maximum of 10 years, you are given:

(i) Expenses of 100 are payable at the end of each year including the year of death.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate the annual gross premium using the equivalence principle.

(A) 790

(B) 800

(C) 810

(D) 820

(E) 830

[This is a modified version of Question 9 on the Spring 2016 Multiple Choice exam.]

6.38. For an n-year endowment insurance of 1000 on (x), you are given:

(i) Death benefits are payable at the moment of death.

(ii) Premiums are payable annually at the beginning of each year.

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

(iv) $i = 0.05$

(v) ${}_nE_x = 0.172$

(vi) $\bar{A}_{x:\overline{n|}} = 0.192$

Calculate the annual net premium for this insurance.

(A) 10.1

(B) 11.3

(C) 12.5

(D) 13.7

(E) 14.9

[This was Question 10 on the Spring 2016 Multiple Choice exam.]

6.39. XYZ Insurance writes 10,000 fully discrete whole life insurance policies of 1000 on lives age 40 and an additional 10,000 fully discrete whole life policies of 1000 on lives age 80.

XYZ used the following assumptions to determine the net premiums for these policies:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

During the first ten years, mortality did follow the Standard Ultimate Life Table.

Calculate the average net premium per policy in force received at the beginning of the eleventh year.

(A) 29

(B) 32

(C) 35

(D) 38

(E) 41

[This is a modified version of Question 11 on the Spring 2016 Multiple Choice exam.]

6.40. For a special fully discrete whole life insurance, you are given:

(i) The death benefit is $1000(1.03)^k$ for death in policy year k, for $k = 1, 2, 3...$

(ii) $q_x = 0.05$

(iii) $i = 0.06$

(iv) $\ddot{a}_{x+1} = 7.00$

(v) The annual net premium for this insurance at issue age x is 110.

Calculate the annual net premium for this insurance at issue age $x+1$.

(A) 110

(B) 112

(C) 116

(D) 120

(E) 122

[This was Question 17 on the Spring 2016 Multiple Choice exam.]

6.41. For a special fully discrete 2-year term insurance on (x), you are given:

(i) $q_x = 0.01$

(ii) $q_{x+1} = 0.02$

(iii) $i = 0.05$

(iv) The death benefit in the first year is 100,000.

(v) Both the benefits and premiums increase by 1% in the second year.

Calculate the annual net premium in the first year.

(A) 1410

(B) 1417

(C) 1424

(D) 1431

(E) 1438

[This was Question 9 on the Fall 2016 Multiple Choice exam.]

6.42. For a fully discrete 3-year endowment insurance of 1000 on (*x*), you are given:

(i) $\mu_{x+t} = 0.06$, for $0 \le t \le 3$.

(ii) $\delta = 0.06$

(iii) The annual premium is 315.80.

(iv) L_0 is the present value random variable for the loss at issue for this insurance.

Calculate $\Pr[L_0 > 0]$.

(A) 0.03

(B) 0.06

(C) 0.08

(D) 0.11

(E) 0.15

[This was Question 10 on the Fall 2016 Multiple Choice exam.]

6.43. For a fully discrete, 5-payment 10-year term insurance of 200,000 on (30), you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) The following expenses are incurred at the beginning of each respective year:

	Year 1		Years 2 - 10	
	Percent of Premium	Per Policy	Percent of Premium	Per Policy
Taxes	5%	0	5%	0
Commissions	30%	0	10%	0
Maintenance	0%	8	0%	4

(iii) $i = 0.05$

(iv) $\ddot{a}_{30:\overline{5}|} = 4.5431$

Calculate the annual gross premium using the equivalence principle.

(A) 150

(B) 160

(C) 170

(D) 180

(E) 190

[This is a modified version of Question 11 on the Fall 2016 Multiple Choice exam.]

6.44. For a special fully discrete 10-year deferred whole life insurance of 100 on (50), you are given:

(i) Premiums are payable annually, at the beginning of each year, only during the deferral period.

(ii) For deaths during the deferral period, the benefit is equal to the return of all premiums paid, without interest.

(iii) $i = 0.05$

(iv) $\ddot{a}_{50} = 17.0$

(v) $\ddot{a}_{60} = 15.0$

(vi) ${}_{10}E_{50} = 0.60$

(vii) $(IA)^{1}_{50:\overline{10}|} = 0.15$

Calculate the annual net premium for this insurance.

(A) 1.3

(B) 1.6

(C) 1.9

(D) 2.2

(E) 2.5

[This was Question 7 on the Spring 2017 Multiple Choice exam.]

6.45. For a fully continuous whole life insurance of 100,000 on (35), you are given:

(i) The annual rate of premium is 560.

(ii) Mortality follows the Standard Ultimate Life Table.

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

(iv) $i = 0.05$

Calculate the 75th percentile of the loss at issue random variable for this policy.

(A) 610

(B) 630

(C) 650

(D) 670

(E) 690

[This is a modified version of Question 8 on the Spring 2017 Multiple Choice exam.]

6.46. For a special 10-year deferred whole life annuity-due of 300 per year issued to (55), you are given:

(i) Annual premiums are payable for 10 years.

(ii) If death occurs during the deferral period, all premiums paid are returned without interest at the end of the year of death.

(iii) $\ddot{a}_{55} = 12.2758$

(iv) $\ddot{a}_{55:\overline{10}|} = 7.4575$

(v) $(IA)^{1}_{55:\overline{10}|} = 0.51213$

Calculate the level net premium.

(A) 195

(B) 198

(C) 201

(D) 204

(E) 208

[This was Question 7 on the Fall 2017 Multiple Choice exam.]

6.47. For a 10-year deferred whole life annuity-due with payments of 100,000 per year on (70), you are given:

(i) Annual gross premiums of G are payable for 10 years.

(ii) First year expenses are 75% of premium.

(iii) Renewal expenses for years 2 and later are 5% of premium during the premium paying period.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) $i = 0.05$

Calculate G using the equivalence principle.

(A) 64,900

(B) 65,400

(C) 65,900

(D) 66,400

(E) 66,900

[This is a modified version of Question 8 on the Fall 2017 Multiple Choice exam.]

6.48. For a special fully discrete 5-year deferred 3-year term insurance of 100,000 on (x) you are given:

(i) There are two premium payments, each equal to P. The first is paid at the beginning of the first year and the second is paid at the end of the 5-year deferral period.

(ii) The following probabilities:

$${}_5p_x = 0.95$$

$$q_{x+5} = 0.02, \quad q_{x+6} = 0.03, \quad q_{x+7} = 0.04$$

(iii) $i = 0.06$

Calculate P using the equivalence principle.

(A) 3195

(B) 3345

(C) 3495

(D) 3645

(E) 3895

[This was Question 9 on the Fall 2017 Multiple Choice exam.]

6.49. For a special whole life insurance of 100,000 on (40), you are given:

(i) The death benefit is payable at the moment of death.

(ii) Level gross premiums are payable monthly for a maximum of 20 years.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

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

(vi) Initial expenses are 200.

(vii) Renewal expenses are 4% of each premium including the first.

(viii) Gross premiums are calculated using the equivalence principle.

Calculate the monthly gross premium.

(A) 66

(B) 76

(C) 86

(D) 96

(E) 106

[This is a modified version of Question 10 on the Fall 2017 Multiple Choice exam.]

6.50. On July 15, 2017, XYZ Corp buys fully discrete whole life insurance policies of 1,000 on each of its 10,000 workers, all age 35. It uses the death benefits to partially pay the premiums for the following year.

You are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) The insurance is priced using the equivalence principle.

Calculate XYZ Corp's expected net cash flow from these policies during July 2018.

(A) -47,000

(B) -48,000

(C) -49,000

(D) -50,000

(E) -51,000

[This is a modified version of Question 13 on the Fall 2017 Multiple Choice exam.]

6.51. For a special 10-year deferred whole life annuity-due of 50,000 on (62), you are given:

(i) Level annual net premiums are payable for 10 years.

(ii) A death benefit, payable at the end of the year of death, is provided only over the deferral period and is the sum of the net premiums paid without interest.

(iii) $\ddot{a}_{62} = 12.2758$

(iv) $\ddot{a}_{62:\overline{10}|} = 7.4574$

(v) $A^{1}_{62:\overline{10}|} = 0.0910$

(vi) $\sum_{k=1}^{10} A^{1}_{62:\overline{k}|} = 0.4891$

Calculate the net premium for this special annuity.

(A) 34,400

(B) 34,500

(C) 34,600

(D) 34,700

(E) 34,800

[This is a modified version of Question 14 on the Fall 2013 Multiple Choice exam.]

7.1. For a special fully discrete whole life insurance on (40), you are given:

(i) The death benefit is 50,000 in the first 20 years and 100,000 thereafter.

(ii) Level net premiums of 875 are payable for 20 years.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate ${}_{10}V$, the net premium reserve at the end of year 10 for this insurance.

(A) 11,090

(B) 11,120

(C) 11,150

(D) 11,180

(E) 11,210

[This is a modified version of Question 4 on the Fall 2012 Multiple Choice exam.]

7.2. A special fully discrete 2-year endowment insurance with a maturity value of 2000 is issued to (x). The death benefit is 2000 plus the net premium reserve at the end of the year of death. For year 2, the net premium reserve is the net premium reserve just before the maturity benefit is paid.

You are given:

(i) $i = 0.10$

(ii) $q_x = 0.150$ and $q_{x+1} = 0.165$

Calculate the level annual net premium.

(A) 1070

(B) 1110

(C) 1150

(D) 1190

(E) 1230

[This is a modified version of Question 5 on the Fall 2012 Multiple Choice exam.]

7.3. For a whole life insurance of 1000 with semi-annual premiums on (80), you are given:

(i) A gross premium of 60 is payable every 6 months starting at age 80.

(ii) Commissions of 10% are paid each time a premium is paid.

(iii) Death benefits are paid at the end of the quarter of death.

(iv) ${}_tV$ denotes the gross premium reserve at time *t*.

(v) ${}_{10.75}V = 753.72$

(vi)

t	l_{90+t}
0	1000
0.25	898
0.50	800
0.75	706

(vii) $i^{(4)} = 0.08$

Calculate ${}_{10.25}V$.

(A) 680

(B) 690

(C) 700

(D) 710

(E) 730

[This was Question 17 on the Fall 2012 Multiple Choice exam.]

7.4. For a special fully discrete whole life insurance on (40), you are given:

(i) The death benefit is 1000 during the first 11 years and 5000 thereafter.

(ii) Expenses, payable at the beginning of the year, are 100 in year 1 and 10 in years 2 and later.

(iii) π is the level annual premium, determined using the equivalence principle.

(iv) $G = 1.02 \times \pi$ is the level annual gross premium.

(v) Mortality follows the Standard Ultimate Life Table.

(vi) $i = 0.05$

(vii) ${}_{11}E_{40} = 0.57949$

Calculate the gross premium reserve at the end of year 1 for this insurance.

(A) -82

(B) -74

(C) -66

(D) -58

(E) -50

[This is a modified version of Question 18 on the Fall 2012 Multiple Choice exam.]

7.5. A life insurance company issues fully discrete 20-year term insurance policies of 1000.

You are given:

(i) Expected mortality follows the Standard Ultimate Life Table.

(ii) Death is the only decrement.

(iii) ${}_3V$, the gross reserve at the end of year 3, is 3.47.

On January 1, 2009, the company sold 10,000 of these policies to lives all aged 45. You are also given:

(i) During the first two years, there were 10 actual deaths from these policies.

(ii) During 2011, there were 6 actual deaths from these policies.

Calculate the company's gain due to mortality for the year 2011.

(A) 3140

(B) 3150

(C) 3160

(D) 3170

(E) 3180

[This is a modified version of Question 23 on the Fall 2012 Multiple Choice exam.]

7.6. For a special fully continuous 10-year increasing term insurance, you are given:

(i) The death benefit is payable at the moment of death and increases linearly from 10,000 to 110,000.

(ii) $\mu = 0.01$

(iii) $\delta = 0.05$

(iv) The annual premium rate is 450.

(v) Premium-related expenses equal 2% of premium, incurred continuously.

(vi) Claims-related expenses equal 200 at the moment of death.

(vii) ${}_tV$ denotes the gross premium reserve at time *t* for this insurance.

(viii) You estimate ${}_{9.6}V$ using Euler's method with step size 0.2 and the derivative of ${}_tV$ at time 9.6.

(ix) Your estimate of ${}_{9.8}V$ is 126.68.

Calculate the estimate of ${}_{9.6}V$.

(A) 230

(B) 250

(C) 270

(D) 280

(E) 290

[This was Question 6 on the Fall 2012 Multiple Choice exam.]

7.7. 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 net premium is 647.46 .

(iii) The net premium reserve at the end of year 4 is 1405.08 .

(iv) $q_{x+4} = 0.04561$

(v) $i = 0.03$

Calculate the net premium reserve at the end of 4.5 years.

(A) 1570

(B) 1680

(C) 1750

(D) 1830

(E) 1900

[This is a modified version of Question 9 on the Spring 2013 Multiple Choice exam.]

7.8. 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 Standard Ultimate Life Table.

(ii) $i = 0.05$

(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 103% of the net premium.

(vi) ${}_0L$ is the aggregate present value of future loss at issue random variable.

Calculate $\Pr({}_0L < 40,000)$, using the normal approximation.

(A) 0.75

(B) 0.79

(C) 0.83

(D) 0.87

(E) 0.91

[This is a modified version of Question 15 on the Spring 2013 Multiple Choice exam.]

7.9. 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 Standard Ultimate Life Table.

(iv) $i = 0.05$

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

(A) -2

(B) -8

(C) -12

(D) -21

(E) -25

[This is a modified version of Question 16 on the Spring 2013 Multiple Choice exam.]

7.10. 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) $\mu_{x+t}^{\mathrm{NS}} = 0.1, \quad t > 0$

(v) $q_{x+k}^{\mathrm{S}} = 1.5 q_{x+k}^{\mathrm{NS}}$ 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) $-26,000$

[This was Question 18 on the Spring 2013 Multiple Choice exam.]

7.11. 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

[This was Question 22 on the Spring 2013 Multiple Choice exam.]

7.12. For a fully discrete whole life insurance of 1000 on a select life [70], you are given:

(i) Ultimate mortality follows the Standard Ultimate Life Table.

(ii) During the three-year select period, $q_{[x]+k} = (0.7 + 0.1k)\, q_{x+k},\ \ k = 0, 1, 2.$

(iii) $i = 0.05$

(iv) The net premium for this insurance is 35.168.

Calculate ${}_1V$, the net premium reserve at the end of year 1 for this insurance.

(A) 25.25

(B) 27.30

(C) 29.85

(D) 31.60

(E) 33.35

[This is a modified version of Question 6 on the Fall 2013 Multiple Choice exam.]

7.13. For a semi-continuous 20-year endowment insurance of 100,000 on (45), you are given:

(i) Net premiums of 253 are payable monthly.

(ii) Mortality follows the Standard Ultimate Life Table.

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

(iv) $i = 0.05$

Calculate ${}_{10}V$, the net premium reserve at the end of year 10 for this insurance.

(A) 38,100

(B) 38,300

(C) 38,500

(D) 38,700

(E) 38,900

[This is a modified version of Question 7 on the Fall 2013 Multiple Choice exam.]

7.14. For a fully discrete whole life insurance of 100,000 on (45), you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) Commission expenses are 60% of the first year's gross premium and 2% of renewal gross premiums.

(iv) Administrative expenses are 500 in the first year and 50 in each renewal year.

(v) All expenses are payable at the start of the year.

(vi) The gross premium, calculated using the equivalence principle, is 977.60.

Calculate ${}_5V^e$, the expense reserve at the end of year 5 for this insurance.

(A) -1070

(B) -1020

(C) -970

(D) -920

(E) -870

[This is a modified version of Question 8 on the Fall 2013 Multiple Choice exam.]

7.15. For a fully discrete whole life insurance of 10,000 on (45), you are given:

(i) $i = 0.05$

(ii) ${}_0L$ denotes the loss at issue random variable based on the net premium.

(iii) If $K_{45} = 10,$ then ${}_0L = 4450.$

(iv) $\ddot{a}_{55} = 13.4205$

Calculate ${}_{10}V,$ the net premium reserve at the end of year 10 for this insurance.

(A) 1010

(B) 1460

(C) 1820

(D) 2140

(E) 2300

[This is a modified version of Question 17 on the Fall 2013 Multiple Choice exam.]

7.16. For two fully continuous whole life insurance policies on (x), you are given:

(i)

	Death Benefit	Annual Premium Rate	Variance of the Present Value of Future Loss at t
Policy A	1	0.10	0.455
Policy B	2	0.16	-

(ii) $\delta = 0.06$

Calculate the variance of the present value of future loss at t for Policy B.

(A) 0.9

(B) 1.4

(C) 2.0

(D) 2.9

(E) 3.4

[This was Question 12 on the Spring 2014 Multiple Choice exam.]

7.17. For a special fully discrete 25-year endowment insurance on (44), you are given:

(i) The death benefit is $(26-k)$ for death in year k, for $k=1,2,3\ldots 25$.

(ii) The endowment benefit in year 25 is 1.

(iii) $q_{55}=0.15$

(iv) $i=0.04$

(v) ${}_{11}V$, the net premium reserve at the end of year 11, is 5.00.

(vi) ${}_{24}V$, the net premium reserve at the end of year 24, is 0.60.

Calculate ${}_{12}V$, the net premium reserve at end of year 12.

(A) 3.63

(B) 3.74

(C) 3.88

(D) 3.98

(E) 4.09

[This was Question 13 on the Spring 2014 Multiple Choice exam.]

7.18. For a fully discrete 30-year endowment insurance of 1000 on (40), you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

Calculate the full preliminary term (FPT) reserve for this policy at the end of year 10.

(A) 180

(B) 185

(C) 190

(D) 195

(E) 200

[This is a modified version of Question 14 on the Spring 2014 Multiple Choice exam.]

7.19. Your company issues whole life annuities to a group of lives age 70. For each policy, you are given:

(i) The annuity pays 2000 at the end of each year.

(ii) The single gross premium is 26,600.

(iii) Profits are based on gross premium reserves.

(iv) The gross premium reserve at the end of year 10 is 8929.18 per policy.

(v) Expenses are paid at the end of each year for any policyholder who does not die during the year.

During year 11, anticipated and actual experience are as follows:

(a)

	Anticipated	Actual
Mortality	$q_{80} = 0.11$	200 deaths
Interest	$i = 0.03$	$i = 0.04$
Expenses	30 per policy	35 per policy

(b) 1000 such policies are in force at the beginning of year 11.

For year 11, you calculate the gain due to interest prior to calculating the gain from other sources.

Calculate the gain due to interest during year 11.

(A) 87,560

(B) 87,902

(C) 88,435

(D) 88,880

(E) 89,292

[This was Question 15 on the Spring 2014 Multiple Choice exam.]

7.20. For a fully discrete whole life insurance of 100,000 on (45), you are given:

(i) The gross premium reserve at duration 5 is 5500 and at duration 6 is 7100.

(ii) $q_{50} = 0.009$

(iii) $i = 0.05$

(iv) Renewal expenses at the start of each year are 50 plus 4% of the gross premium.

(v) Claim expenses are 200.

Calculate the gross premium.

(A) 2200

(B) 2250

(C) 2300

(D) 2350

(E) 2400

[This was Question 13 on the Fall 2014 Multiple Choice exam.]

7.21. For a fully discrete whole life insurance of 100 on (*x*), you are given:

(i) $q_{x+15} = 0.10$

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

(iii) $i = 0.05$

(iv) ${}_tV$ denotes the net premium reserve at time *t*.

(v) ${}_{16}V = 49.78$

Calculate ${}_{15.6}V$.

(A) 49.7

(B) 50.0

(C) 50.3

(D) 50.6

(E) 50.9

[This is a modified version of Question 14 on the Fall 2014 Multiple Choice exam.]

7.22. For a fully discrete 5-payment whole life insurance of 1000 on (80), you are given:

(i) The gross premium is 130.

(ii) $q_{80+k} = 0.01(k+1), \quad k = 0, 1, 2, .., 5$

(iii) $v = 0.95$

(iv) $1000A_{86} = 683$

(v) ${}_3L$ is the prospective loss random variable at time 3, based on the gross premium.

Calculate $E\left[{}_3L\right]$.

(A) 330

(B) 350

(C) 360

(D) 380

(E) 390

[This was Question 15 on the Fall 2014 Multiple Choice exam.]

7.23. For a fully discrete whole life insurance of 1 on (x), you are given:

(i) $q_{x+10} = 0.02067$

(ii) $v^2 = 0.90703$

(iii) $A_{x+11} = 0.52536$

(iv) ${}^2A_{x+11} = 0.30783$

(v) ${}_kL$ is the prospective loss random variable at time k.

Calculate $\dfrac{\operatorname{Var}\left({}_{10}L\right)}{\operatorname{Var}\left({}_{11}L\right)}$.

(A) 1.006

(B) 1.010

(C) 1.014

(D) 1.018

(E) 1.022

[This was Question 16 on the Fall 2014 Multiple Choice exam.]

7.24. For a fully discrete whole life insurance of 1 on (x), you are given:

(i) The net premium reserve at the end of the first year is 0.012.

(ii) $q_x = 0.009$

(iii) $i = 0.04$

Calculate $\ddot{a}_x$.

(A) 17.1

(B) 17.6

(C) 18.1

(D) 18.6

(E) 19.1

[This was Question 14 on the Spring 2015 Multiple Choice exam.]

7.25. For a fully discrete whole life insurance of 100,000 on (40) you are given:

(i) Expenses incurred at the beginning of the first year are 300 plus 50% of the first year premium.

(ii) Renewal expenses, incurred at the beginning of the year, are 10% of each of the renewal premiums.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

(v) Gross premiums are calculated using the equivalence principle.

Calculate the gross premium reserve for this insurance immediately after the second premium and associated renewal expenses are paid.

(A) 200

(B) 340

(C) 560

(D) 720

(E) 1060

[This is a modified version of Question 18 on the Spring 2015 Multiple Choice exam.]

7.26. For a fully discrete whole life insurance policy on (30) with a death benefit of 150,000, you are given:

(i) Reserves at the end of years 20 and 21 are 24,496 and 26,261, respectively.

(ii) The gross premium is 1212.

(iii) Expected expenses equal 60 plus $W\%$ of the gross premium payable at the beginning of each year.

(iv) $q_{50} = 0.004736.$

(v) The expected interest rate is 8%.

(vi) The expected profit in the 21st policy year for a policy in force at the beginning of that year is 722.

Calculate $W\%$.

(A) 8%

(B) 9%

(C) 10%

(D) 11%

(E) 12%

[This was Question 12 on the Fall 2015 Multiple Choice exam.]

7.27. A life insurance company sells a portfolio of 1000 fully discrete whole life insurance policies of 500, on lives age 45.

You are given:

(i) There are no expenses.

(ii) The annual gross premium is 8.80 per policy.

(iii) At the end of the third policy year:
- The reserve per policy is 19.90.
- 980 policies remain in force.

(iv) During the fourth policy year:
- The interest earned on the assets that back these policies was $j\%$.
- There were 7 deaths.

(v) At the end of the fourth policy year the reserve per policy is 27.77.

(vi) There was no gain or loss during the fourth policy year.

Calculate $j\%$.

(A) 6.5%

(B) 7.0%

(C) 7.5%

(D) 8.0%

(E) 8.5%

[This was Question 14 on the Fall 2015 Multiple Choice exam.]

7.28. For a fully discrete whole life insurance of 1000 on (35), you are given:

(i) First year expenses are 30% of the gross premium plus 300.

(ii) Renewal expenses are 4% of the gross premium plus 30.

(iii) All expenses are incurred at the beginning of the policy year.

(iv) Gross premiums are calculated using the equivalence principle.

(v) The gross premium reserve at the end of the first policy year is R.

(vi) Using the Full Preliminary Term Method, the modified reserve at the end of the first policy year is S.

(vii) Mortality follows the Standard Ultimate Life Table.

(viii) $i = 0.05$.

Calculate $R - S$.

(A) −280

(B) −140

(C) 0

(D) 140

(E) 280

[This is a modified version of Question 15 on the Fall 2015 Multiple Choice exam.]

7.29. A special fully discrete 10-payment 10-year deferred whole life annuity-due on (55) of 1000 per year provides for a return of premiums without interest in the event of death within the first 10 years. You are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) $(IA)^{1}_{55:\overline{10|}} = 0.14743$

Calculate ${}_9V$, the net premium reserve at the end of year 9.

(A) 11,540

(B) 11,650

(C) 11,760

(D) 11,870

(E) 11,980

[This is a modified version of Question 16 on the Fall 2015 Multiple Choice exam.]

7.30. For two fully discrete whole life insurance policies on (x), you are given:

(i)

	Death Benefit	Annual Net Premium	Variance of Loss at Issue
Policy 1	8	1.250	20.55
Policy 2	12	1.875	*W*

(ii) $i = 0.06$

(iii) The two policies are priced using the same mortality table.

Calculate *W*.

(A) 30.8

(B) 38.5

(C) 46.2

(D) 53.9

(E) 61.6

[This was Question 12 on the Spring 2016 Multiple Choice exam.]

7.31 For a 40-year endowment insurance of 10,000 issued to (25), you are given:

(i) $i = 0.04$

(ii) $p_{25} = 0.995$

(iii) $\ddot{a}_{25:\overline{20|}} = 11.087$

(iv) $\ddot{a}_{25:\overline{40|}} = 16.645$

(v) The annual level net premium is 216.

A modified premium reserving method is used for this policy, where the modified premiums are:

I. A first year premium equal to the first year net cost of insurance,

II. Level premiums of β for years 2 through 20, and

III. Level premiums of 216 thereafter.

Calculate β.

(A) 140

(B) 170

(C) 200

(D) 230

(E) 260

[This was Question 15 on the Spring 2016 Multiple Choice exam.]

7.32. For a fully discrete whole life insurance policy of 1,000,000 on (50), you are given:

(i) The annual gross premium, calculated using the equivalence principle, is 11,800.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate the expense loading, P^e, for this policy.

(A) 480

(B) 580

(C) 680

(D) 780

(E) 880

[This is a modified version of Question 8 on the Fall 2016 Multiple Choice exam.]

7.33. For a fully discrete whole life insurance policy of 100,000 on [55], a professional skydiver, you are given:

(i) Premiums are paid annually.

(ii) Mortality follows a 2-year select and ultimate table.

(iii) $i = 0.04$

(iv) The following table of values for $A_{[x]+t}$:

x	$A_{[x]}$	$A_{[x]+1}$	A_{x+2}
55	0.23	0.24	0.25
56	0.25	0.26	0.27
57	0.27	0.28	0.29
58	0.29	0.30	0.31

Calculate the Full Preliminary Term reserve at time 3.

(A) 2700

(B) 3950

(C) 5200

(D) 6450

(E) 7800

[This was Question 12 on the Fall 2016 Multiple Choice exam.]

7.34. For a special fully discrete 2-year endowment insurance on (*x*), you are given:

(i) The death benefit for year *k* is 25,000*k* plus the net premium reserve at the end of year *k*, for $k = 1, 2.$ For year 2, this net premium reserve is the net premium reserve just before the maturity benefit is paid.

(ii) The maturity benefit is 50,000.

(iii) $p_x = p_{x+1} = 0.85$

(iv) $i = 0.05$

(v) *P* is the level annual net premium.

Calculate *P*.

(A) 27,650

(B) 27,960

(C) 28,200

(D) 28,540

(E) 28,730

[This was Question 13 on the Fall 2016 Multiple Choice exam.]

7.35. XYZ Life Company issues 5,000 fully discrete whole life insurance policies of 10,000 to lives each age 50, with independent future lifetimes.

You are given:

(i) The annual gross premium is 220 per policy.

(ii) Each policy is assumed to incur an expense of 30 at the beginning of each year.

(iii) Gross premiums and reserves are calculated using $q_{53} = 0.0068$ and $i = 5\%$.

(iv) At the end of the third policy year:
- The gross premium reserve per policy is 505
- There are 4,885 policies in force

(v) During the fourth policy year:
- The actual expense incurred per policy was 34
- There were a total of 42 actual deaths
- The earned interest rate was 6%

Calculate the profit for the fourth policy year.

(A) -97,000

(B) -83,000

(C) -69,000

(D) -55,000

(E) -41,000

[This was Question 16 on the Fall 2016 Multiple Choice exam.]

7.36. The gross annual premium, *G*, for a fully discrete 5-year endowment insurance of 1000 issued on (x) is calculated using the equivalence principle.

You are given:

(i) $1000P_{x:\overline{5}|} = 187.00$

(ii) The expense reserve at the end of the first year, ${}_1V^e = -38.70$

(iii) $q_x = 0.008$

(iv) Expenses, payable at the beginning of the year, are:

Year	Percent of Premium	Per Policy
First	25%	10
Renewal	5%	5

(v) $i = 0.03$

Calculate *G*.

(A) 200

(B) 213

(C) 226

(D) 239

(E) 252

[This was Question 17 on the Fall 2016 Multiple Choice exam.]

7.37. For a fully continuous whole life insurance of 10,000 issued to (40) you are given the following information:

(i) Premiums are paid at a rate of 100 per year.

(ii) $\delta = 0.05$

(iii) $\mu_{70.5} = 0.038$

(iv) For $t = 30.5$, $\dfrac{d}{dt}\,{}_{t}V = 292$

Calculate ${}_{30.5}V$.

(A) 5000

(B) 5500

(C) 6000

(D) 6500

(E) 7000

[This was Question 10 on the Spring 2017 Multiple Choice exam.]

7.38. For a fully discrete 10-payment whole life insurance of H on (45), you are given:

(i) Expenses payable at the beginning of each year are as follows:

Expense Type	First Year	Years 2-10	Years 11+
Per policy	100	20	10
% of Premium	105%	5%	0%

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) The gross annual premium, calculated using the equivalence principle, is of the form:

$$G = gH + f$$

where g is the premium rate per 1 of insurance and f is the per policy fee.

Calculate f.

(A) 42.00

(B) 44.20

(C) 46.40

(D) 48.60

(E) 50.80

[This is a modified version of Question 11 on the Spring 2017 Multiple Choice exam.]

7.39. A warranty pays 2000 at the end of the year of the first failure if a washing machine fails within three years of purchase. The warranty is purchased with a single premium, *G*, paid at the time of purchase of the washing machine.

You are given:

(i) 10% of the washing machines that are working at the start of each year fail by the end of that year.

(ii) $i = 0.08$

(iii) The sales commission is 35% of *G*.

(iv) *G* is calculated using the equivalence principle.

Calculate *G*.

(A) 630

(B) 660

(C) 690

(D) 720

(E) 750

[This was Question 12 on the Spring 2017 Multiple Choice exam.]

7.40. For a fully discrete whole life insurance of 1000 on (x), you are given:

(i) For calculating gross premium reserves in year 8, the following assumptions are made:

- $q_{x+7} = 0.03$
- Annual expenses of 100, payable at the beginning of the year
- $i = 0.07$

(ii) Actual experience during year 8 for this policy is:

- The policy is in force at the end of year 8.
- The annual expenses are 75, paid at the beginning of the year.
- The interest earned is 3%.

(iii) Gain by source for year 8 is analyzed in the following order: mortality, expense, interest.

Calculate the gain from expense in policy year 8.

(A) 25.00

(B) 25.75

(C) 26.75

(D) 27.50

(E) 28.50

[This was Question 16 on the Spring 2017 Multiple Choice exam.]

7.41. For a fully discrete whole life insurance of 200,000 on (45), you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) The annual premium is determined using the equivalence principle.

Calculate the standard deviation of L_0, the present value random variable for the loss at issue.

(A) 25,440

(B) 30,440

(C) 35,440

(D) 40,440

(E) 45,440

[This is a modified version of Question 12 on the Fall 2017 Multiple Choice exam.]

7.42. For a special fully discrete whole life insurance of 1,000 on (45), you are given:

(i) The net premiums for year *k* are:

$$\begin{cases} P, & k = 1, 2, \ldots, 20 \\ P + W, & k = 21, 22, \ldots \end{cases}$$

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) ${}_{20}V$, the net premium reserve at the end of the 20th year, is 0.

Calculate W.

(A) 12

(B) 16

(C) 20

(D) 24

(E) 28

[This is a modified version of Question 15 on the Fall 2017 Multiple Choice exam.]

7.43. For a fully discrete whole life insurance of *B* on (x), you are given:

(i) Expenses, incurred at the beginning of each year, equal 30 in the first year and 5 in subsequent years.

(ii) The net premium reserve at the end of year 10 is 2290.

(iii) Gross premiums are calculated using the equivalence principle.

(iv) $i = 0.04$

(v) $\ddot{a}_x = 14.8$

(vi) $\ddot{a}_{x+10} = 11.4$

Calculate ${}_{10}V^g$, the gross premium reserve at the end of year 10.

(A) 2190

(B) 2210

(C) 2230

(D) 2250

(E) 2270

[This was Question 16 on the Fall 2017 Multiple Choice exam.]

7.44. Ten years ago Jacob, then age 25, purchased a fully discrete 10-payment whole life policy of 10,000.

All actuarial calculations for this policy were based on the following:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

(iii) The equivalence principle

L_{10} is the present value of future losses random variable at time 10.

At the end of policy year 10, the interest rate used to calculate L_{10} is changed to 0%.

Calculate the increase in $E[L_{10}]$ that results from this change.

(A) 5035

(B) 6035

(C) 7035

(D) 8035

(E) 9035

[This is a modified version of Question 18 on the Fall 2017 Multiple Choice exam.]

7.45. For a fully discrete 3-year endowment insurance of 1000 on (*x*), you are given:

(i) Expenses, payable at the beginning of the year, are:

Year(s)	Percent of Premium	Per Policy
1	20%	15
2 and 3	8%	5

(ii) The expense reserve at the end of year 2 is -23.64.

(iii) The gross annual premium calculated using the equivalence principle is $G = 368.05$.

(iv) $G = 1000P_{x:\overline{3}|} + P^e$, where P^e is the expense loading.

Calculate $P_{x:\overline{3}|}$.

(A) 0.290

(B) 0.295

(C) 0.300

(D) 0.305

(E) 0.310

[This was Question 16 on the Spring 2014 Multiple Choice exam.]

8.1. A party of scientists arrives at a remote island. Unknown to them, a hungry tyrannosaur lives on the island. You model the future lifetimes of the scientists as a three-state model, where:

State 0: no scientists have been eaten.

State 1: exactly one scientist has been eaten.

State 2: at least two scientists have been eaten.

You are given:

(i) Until a scientist is eaten, they suspect nothing, so

$$\mu_t^{01} = 0.01 + 0.02 \times 2^t, \quad t > 0$$

(ii) Until a scientist is eaten, they suspect nothing, so the tyrannosaur may come across two together and eat both, with

$$\mu_t^{02} = 0.5 \times \mu_t^{01}, \quad t > 0$$

(iii) After the first death, scientists become much more careful, so

$$\mu_t^{12} = 0.01, \quad t > 0$$

Calculate the probability that no scientists are eaten in the first year.

(A) 0.928

(B) 0.943

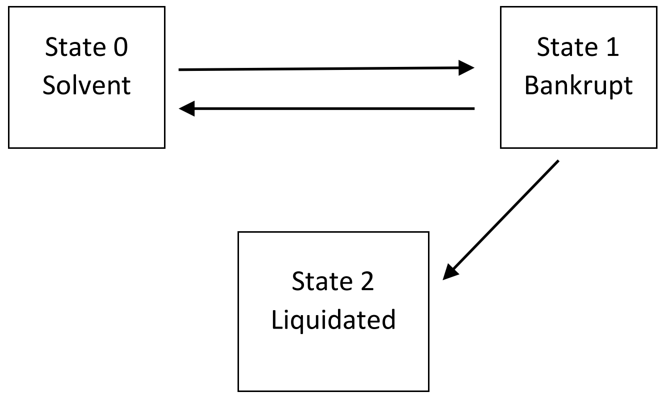
(C) 0.951

(D) 0.956

(E) 0.962

[This was Question 12 on the Fall 2012 Multiple Choice exam.]

8.2. You are evaluating the financial strength of companies based on the following multiple state model:



For each company, you assume the following constant transition intensities:

(i) $\mu^{01} = 0.02$

(ii) $\mu^{10} = 0.06$

(iii) $\mu^{12} = 0.10$

Using Kolmogorov's forward equations with step $h = 1/2,$ calculate the probability that a company currently Bankrupt will be Solvent at the end of one year.

(A) 0.048

(B) 0.051

(C) 0.054

(D) 0.057

(E) 0.060

[This was Question 16 on the Fall 2012 Multiple Choice exam.]

8.3. An insurance company is designing a special 2-year term insurance. Transitions are modeled as a four-state homogeneous Markov model with states:

(H) Healthy

(Z) infected with virus “Zebra”

(L) infected with virus “Lion”

(D) Death

The annual transition probability matrix is given by:

$$\begin{array}{c} \\ H \\ Z \\ L \\ D \end{array} \begin{array}{c} \begin{array}{cccc} \quad H & \quad\; Z & \quad\; L & \quad\; D \end{array} \\ \begin{pmatrix} 0.90 & 0.05 & 0.04 & 0.01 \\ 0.10 & 0.20 & 0.00 & 0.70 \\ 0.20 & 0.00 & 0.20 & 0.60 \\ 0.00 & 0.00 & 0.00 & 1.00 \end{pmatrix} \end{array}$$

You are given:

(i) Only one transitions can occur during any given year.

(ii) 250 is payable at the end of the year in which you become infected with either virus.

(iii) For lives infected with either virus, 1000 is payable at the end of the year of death.

(iv) The policy is issued only on Healthy lives.

(v) $i = 0.05$

Calculate the actuarial present value of the benefits at policy issue.

(A) 66

(B) 75

(C) 84

(D) 93

(E) 102

[This is a modified version of Question 24 on the Fall 2012 Multiple Choice exam.]

8.4. You are given:

(i) The following excerpt from a triple decrement table:

x	$l_x^{(\tau)}$	$d_x^{(1)}$	$d_x^{(2)}$	$d_x^{(3)}$
50	100,000	490	8,045	1,100
51	90,365	-	8,200	-
52	80,000	-	-	-

(ii) All decrements are uniformly distributed over each year of age in the triple decrement table.

(iii) $q_x'^{(3)}$ is the same for all ages.

Calculate $10,000\, q_{51}'^{(1)}$.

(A) 130

(B) 133

(C) 136

(D) 138

(E) 141

[This was Question 13 on the Fall 2012 Multiple Choice exam.]

8.5. 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:

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

(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

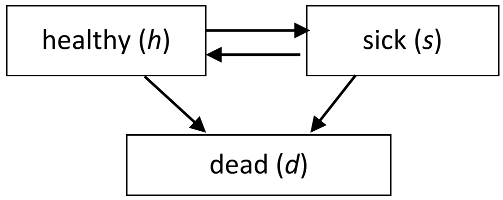
(C) 40,350

(D) 44,470

(E) 48,580

[This was Question 4 on the Spring 2013 Multiple Choice exam.]

8.6. 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 $i,\ j = s, h \text{ or } d$.

(v) δ is the force of interest.

(vi) ${}_tV^{(i)}$ is the reserve at time *t* for an insured in state *i* where $i = s, h \text{ or } d$.

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) $$\frac{d}{dt}{}_tV^{(s)} = \delta\,{}_tV^{(s)} + B - \mu_{x+t}^{sh}\left({}_tV^{(h)} - {}_tV^{(s)}\right)$$

(B) $$\frac{d}{dt}{}_tV^{(s)} = \delta\,{}_tV^{(s)} - B - \mu_{x+t}^{sh}\left({}_tV^{(h)} - {}_tV^{(s)}\right)$$

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

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

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

[This was Question 10 on the Spring 2013 Multiple Choice exam.]

8.7. 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%

[This was Question 13 on the Spring 2013 Multiple Choice exam.]

8.8. In a homogeneous Markov model with three states: Healthy (H), Sick (S), and Dead (D), you are given:

(i) The monthly transition probabilities are:

$$\begin{array}{c} \\ H \\ S \\ D \end{array} \begin{array}{c} \begin{array}{ccc} H & S & D \end{array} \\ \begin{pmatrix} 0.75 & 0.20 & 0.05 \\ 0.30 & 0.50 & 0.20 \\ 0.00 & 0.00 & 1.00 \end{pmatrix} \end{array}$$

(ii) Initially there are 10 Healthy lives with independent future states.

Calculate the probability that exactly 4 lives will die during the first two months.

(A) 0.0005

(B) 0.0245

(C) 0.1132

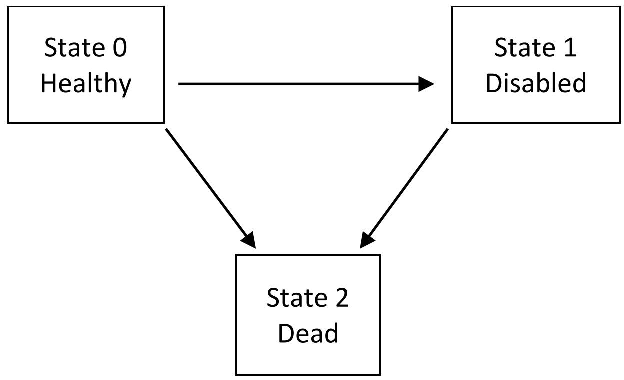
(D) 0.2136

(E) 0.4414

[This was Question 4 on the Fall 2013 Multiple Choice exam.]

8.9. For a multiple state model, you are given:

(i)



(ii) The following forces of transition:

(a) $\mu^{01} = 0.02$

(b) $\mu^{02} = 0.03$

(c) $\mu^{12} = 0.05$

Calculate the conditional probability that a Healthy life on January 1, 2004 is still Healthy on January 1, 2014, given that this person is not Dead on January 1, 2014.

(A) 0.61

(B) 0.68

(C) 0.74

(D) 0.79

(E) 0.83

[This was Question 10 on the Fall 2013 Multiple Choice exam.]

8.10. You are pricing an automobile insurance on (*x*). The insurance pays 10,000 immediately if (*x*) gets into an accident within 5 years of issue. The policy pays only for the first accident and has no other benefits.

You are given:

(i) You model (*x*)'s driving status as a multi-state model with the following 3 states:

0 - low risk, without an accident

1 - high risk, without an accident

2 - has had an accident

(ii) (*x*) is initially in state 0.

(iii) The following transition intensities for $0 \le t \le 5$:

$$\mu_{x+t}^{01} = 0.20 + 0.10t$$

$$\mu_{x+t}^{02} = 0.05 + 0.05t$$

$$\mu_{x+t}^{12} = 0.15 + 0.01t^2$$

No other transitions are possible.

(iv) ${}_3p_x^{01} = 0.4174$

(v) $\delta = 0.02$

(vi) The continuous function $g(t)$ is such that the expected present value of the benefit up to time *a* equals $\int_0^a g(t)dt, \quad 0 \le a \le 5,$ where *t* is the time of the first accident.

Calculate $g(3)$.

(A) 1400

(B) 1500

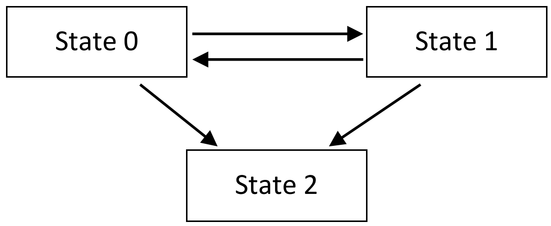
(C) 1600

(D) 1700

(E) 1800

[This was Question 21 on the Fall 2013 Multiple Choice exam.]

8.11. A continuous Markov process is modeled by the following multiple state diagram:



You are given the following constant transition intensities:

(i) $\mu^{01} = 0.08$

(ii) $\mu^{02} = 0.04$

(iii) $\mu^{10} = 0.10$

(iv) $\mu^{12} = 0.05$

For a person in State 1, calculate the probability that the person will continuously remain in State 1 for the next 15 years.

(A) 0.032

(B) 0.105

(C) 0.151

(D) 0.250

(E) 0.350

[This was Question 3 on the Spring 2014 Multiple Choice exam.]

8.12. For a fully discrete 3-year endowment insurance of 100 on (50), you are given:

(i) The following double decrement table, where decrement *d* refers to death and decrement *w* refers to withdrawal:

x	$l_x^{(\tau)}$	$d_x^{(d)}$	$d_x^{(w)}$
50	1000	20	35
51	945	25	25
52	895	30	0

(ii) There are no benefits upon withdrawal.

(iii) $i = 0.05$

Calculate the annual net premium for this policy.

(A) 18

(B) 22

(C) 26

(D) 30

(E) 34

[This was Question 20 on the Spring 2014 Multiple Choice exam.]

8.13. For a double decrement table, you are given:

(i) $q'^{(1)}_x = 0.1$

(ii) $q^{(2)}_x = 0.2$

(iii) Each decrement is uniformly distributed over each year of age in its associated single decrement table.

Calculate $q^{(1)}_x$.

(A) 0.0895

(B) 0.0915

(C) 0.0935

(D) 0.0955

(E) 0.0975

[This was Question 2 on the Fall 2014 Multiple Choice exam.]

8.14. Patients are classified as Sick (S), Critical (C), or Discharged (D). Transitions occur daily according to the following Markov transition matrix:

$$
\begin{array}{cc}
 & \begin{array}{ccc} \text{S} & \text{C} & \text{D} \end{array} \\
\begin{array}{c} \text{S} \\ \text{C} \\ \text{D} \end{array} & \begin{pmatrix} 0.60 & 0.20 & 0.20 \\ 0.10 & 0.50 & 0.40 \\ 0.00 & 0.00 & 1.00 \end{pmatrix}
\end{array}
$$

Calculate the probability that a patient who is classified as Sick today will be classified as Sick three days later.

(A) 0.216

(B) 0.234

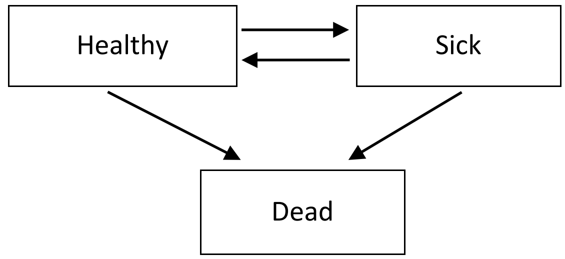
(C) 0.250

(D) 0.267

(E) 0.284

[This is a modified version of Question 3 on the Fall 2014 Multiple Choice exam.]

8.15. You are analyzing the sensitivity of some of the assumptions used in setting the premium rate for a sickness policy. You are basing your calculations on a multiple state model as diagrammed below:



You are given:

(i) Level premiums are paid continuously by Healthy policyholders.

(ii) Level sickness benefits are paid continuously to Sick policyholders.

(iii) There is no death benefit.

Which one of the following changes to the assumptions will be certain to increase the premium rate?

(A) A lower rate of interest and a higher recovery rate from the Sick state.

(B) A lower mortality rate for those in the Healthy state and a lower mortality rate for those in the Sick state.

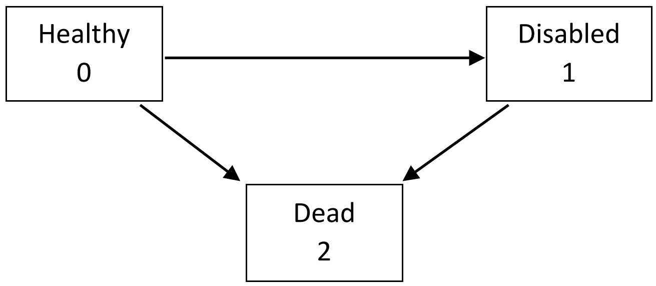
(C) A higher mortality rate for those in the Healthy state and a higher mortality rate for those in the Sick state.

(D) A lower recovery rate from the Sick state and a lower mortality rate for those in the Sick state.

(E) A higher rate of interest and a lower mortality rate for those in the Healthy state.

[This was Question 12 on the Fall 2014 Multiple Choice exam.]

8.16. You are pricing a type of disability insurance using the following model:



The insurance will pay a benefit only if, by age 65, the insured had been disabled for a period of at least one year. You are given the following forces of transition:

(i) $\mu^{01} = 0.02$

(ii) $\mu^{02} = 0.03$

(iii) $\mu^{12} = 0.11$

Calculate the probability that a benefit will be paid for a Healthy life aged 50 who purchases this insurance.

(A) 0.14

(B) 0.16

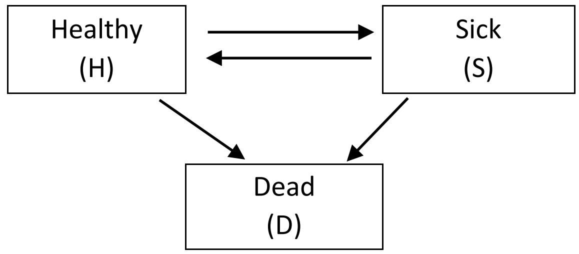
(C) 0.18

(D) 0.20

(E) 0.22

[This was Question 2 on the Spring 2015 Multiple Choice exam.]

8.17. A life insurance company uses the following 3-state Markov model to calculate premiums for a 3-year sickness policy issued to Healthy lives.



The company will pay a benefit of 20,000 at the end of each year if the policyholder is Sick at that time.

The insurance company uses the following transition probabilities, applicable in each of the three years:

	H	S	D
H	0.950	0.025	0.025
S	0.300	0.600	0.100
D	0.000	0.000	1.000

Calculate the expected present value at issue of sickness benefit payments using an interest rate of 6%.

(A) 1805

(B) 1870

(C) 1935

(D) 2000

(E) 2065

[This is a modified version of Question 6 on the Spring 2015 Multiple Choice exam.]

8.18. Johnny Vegas performs motorcycle jumps throughout the year and has injuries in the course of his shows according to the following three-state Markov model:

State 0: No injuries
State 1: Exactly one injury
State 2: At least two injuries

You are given:

(i) Transition intensities between States are per year.

(ii) $\mu_t^{01} = 0.03 + 0.06 \times 2^t, \quad t > 0$

(iii) $\mu_t^{02} = 2.718 \mu_t^{01}, \quad t > 0$

(iv) $\mu_t^{12} = 0.025, \quad t > 0$

Calculate the probability that Johnny, who currently has no injuries, will sustain at least one injury in the next year.

(A) 0.35

(B) 0.39

(C) 0.43

(D) 0.47

(E) 0.51

[This is a modified version of Question 3 on the Fall 2015 Multiple Choice exam.]

8.19. You are using a Markov model for the future repair status of televisions. The three states are:

Fully Functional (F),
Requires Repairs (R), and
Beyond Repair (B).

You are given:

(i) The following annual probability transition matrix:

$$\begin{array}{c} \\ F \\ R \\ B \end{array} \begin{array}{c} \begin{array}{ccc} F & R & B \end{array} \\ \begin{pmatrix} 0.82 & 0.10 & 0.08 \\ 0.60 & 0.05 & 0.35 \\ 0.00 & 0.00 & 1.00 \end{pmatrix} \end{array}$$

(ii) There are now five televisions that are Fully Functional.

(iii) The status of each television is independent of the status of the others.

Calculate the probability that exactly two of these five televisions will be Fully Functional at the end of two years.

(A) 0.10

(B) 0.28

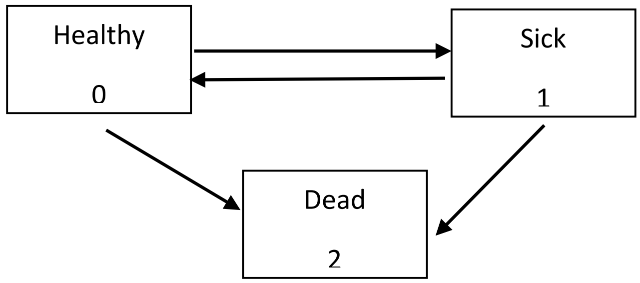
(C) 0.41

(D) 0.54

(E) 0.67

[This was Question 1 on the Spring 2016 Multiple Choice exam.]

8.20. A 5-year sickness insurance policy is based on the following Markov model:



You are given the following constant forces of transition:

(i) $\mu^{01} = 0.05$

(ii) $\mu^{10} = 0.02$

(iii) $\mu^{02} = 0.01$

(iv) $\mu^{12} = 0.06$

Calculate the probability that a Healthy life will become Sick exactly once during the 5 years and remain continuously Sick from that point until the end of the 5 years.

(A) 0.06

(B) 0.09

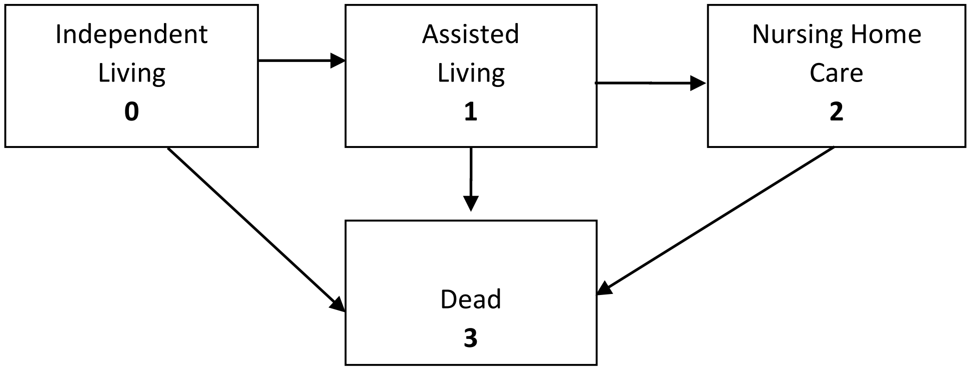
(C) 0.12

(D) 0.15

(E) 0.18

[This was Question 4 on the Spring 2016 Multiple Choice exam.]

8.21. You are given the following Markov model:



The forces of transition are the following:

- $\mu^{01} = 0.01$
- $\mu^{03} = 0.02$
- $\mu^{12} = 0.30$
- $\mu^{13} = 0.40$
- $\mu^{23} = 0.70$

Calculate the probability that a person in Independent Living today will be in Assisted Living at the end of 5 years.

(A) 0.008

(B) 0.010

(C) 0.012

(D) 0.023

(E) 0.034

[This was Question 3 on the Spring 2017 Multiple Choice exam.]

8.22. You are given the following Markov model:

(i) Annual transition probabilities are as follows:

	Healthy	Sick	Terminated
Healthy	0.90	0.05	0.05
Sick	0.30	0.60	0.10
Terminated	0.00	0.00	1.00

(ii) The annual health care costs each year, paid at the middle of the year, for each state, are:

Healthy: 500 Sick: 5000 Terminated: 0

(iii) Transitions occur at the end of the year.

(iv) $\delta = 0.04$

Calculate the actuarial present value of health care costs over the next three years for an individual who is currently Healthy.

(A) 1710

(B) 1760

(C) 1810

(D) 1860

(E) 1910

[This was Question 4 on the Spring 2017 Multiple Choice exam.]

8.23. You are given the following excerpt from a double decrement table:

x	$\ell_x^{(\tau)}$	$q_x^{(1)}$	$q_x^{(2)}$
53	---	0.025	0.030
54	5000	---	0.040
55	4625	0.055	0.050

Calculate ${}_2q_{53}^{(1)}$.

(A) 0.056

(B) 0.057

(C) 0.058

(D) 0.059

(E) 0.060

[This was Question 2 on the Fall 2017 Multiple Choice exam.]

8.24. You are given the following Markov chain model:

(i) Annual transition probabilities between the states Healthy, Sick and Dead, of an organism are as follows:

	Healthy	Sick	Dead
Healthy	0.64	0.16	0.20
Sick	0.36	0.24	0.40
Dead	0	0	1

(ii) Transitions occur at the end of the year.

A population of 1000 organisms starts in the Healthy state. Their future states are independent.

Using the normal approximation without the continuity correction, calculate the probability that there will be at least 625 organisms alive (Healthy or Sick) at the beginning of the third year.

(A) 13.6%

(B) 14.6%

(C) 15.6%

(D) 16.6%

(E) 17.6%

[This was Question 3 on the Fall 2017 Multiple Choice exam.]

8.25. You are given the following extract from a triple decrement table:

x	$\ell_x^{(\tau)}$	$q_x^{(1)}$	$q_x^{(2)}$	$q_x^{(3)}$
40	15,000	0.01	0.04	0.05
41	-	0.04	0.08	0.10

After the table was prepared, you discover that $q_{40}^{(1)}$ should have been 0.02, and that all other numerical values shown above are correct.

Calculate the resultant change in $d_{41}^{(3)}$.

(A) Decrease by 20

(B) Decrease by 15

(C) No Change

(D) Increase by 15

(E) Increase by 20

[This was Question 1 on the Spring 2017 Multiple Choice exam.]

8.26. 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 $\mathrm{Var}(Z)$.

(A) 0

(B) 50

(C) 167

(D) 200

(E) 500

[This was Question 11 on the Spring 2013 Multiple Choice exam.]

8.27. 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	$l_x^{(\tau)}$	$d_x^{(1)}$	$d_x^{(2)}$	$d_x^{(3)}$	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

[This was Question 2 on the Spring 2013 Multiple Choice exam.]

9.1. For two lives, (80) and (90), with independent future lifetimes, you are given:

k	p_{80+k}	p_{90+k}
0	0.9	0.6
1	0.8	0.5
2	0.7	0.4

Calculate the probability that the last survivor will die in the third year.

(A) 0.20

(B) 0.21

(C) 0.22

(D) 0.23

(E) 0.24

[This was Question 1 on the Fall 2012 Multiple Choice exam.]

9.2. Mr. and Mrs. Peters, both age 65, purchase a contract providing the following benefits:

(i) An annuity-due of *R* per year payable while both are alive, reducing to 0.6*R* per year after the death of Mr. Peters as long as Mrs. Peters is alive, and reducing to 0.7*R* per year after the death of Mrs. Peters as long as Mr. Peters is alive.

(ii) A life insurance benefit of 100,000 payable at the end of the year of death of Mr. Peters, whether or not Mrs. Peters is alive.

You are given:

(i) Future lifetimes are independent.

(ii) The mortality of each life follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

(iv) The single net premium for this contract is 1,000,000.

Calculate *R*.

(A) 51,000

(B) 54,000

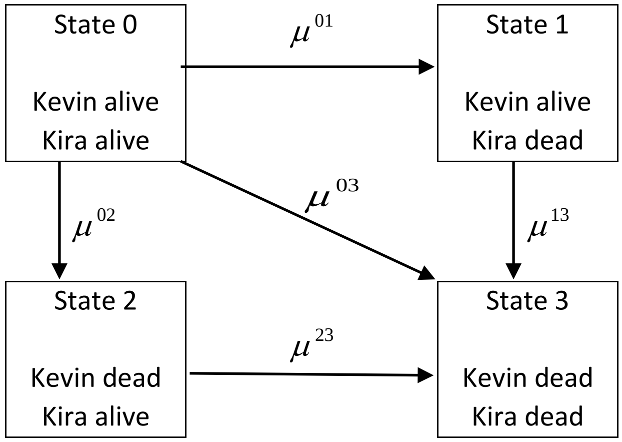
(C) 58,500

(D) 63,000

(E) 68,500

[This is a modified version of Question 6 on the Fall 2014 Multiple Choice exam.]

9.3. The joint lifetime of Kevin, age 65, and Kira, age 60, are dependent lifetimes and 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 ${}_{10}p^{02}_{65:60}$.

(A) 0.046

(B) 0.048

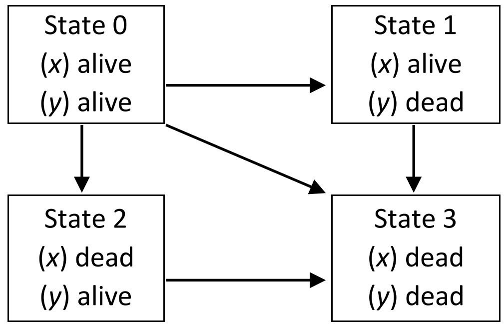
(C) 0.050

(D) 0.052

(E) 0.054

[This is a modified version of Question 5 on the Spring 2013 Multiple Choice exam.]

9.4. The joint mortality of two lives (x) and (y) with dependent future lifetimes is being modeled as a multiple state model:



You are given:

(i) $\mu^{01} = 0.010$

(ii) $\mu^{02} = 0.030$

(iii) $\mu^{03} = 0.005$

(iv) $\delta = 0.05$

A special joint whole life insurance pays 1000 at the moment of simultaneous death, if that occurs, and zero otherwise.

Calculate the actuarial present value of this insurance.

(A) 52.6

(B) 55.6

(C) 87.9

(D) 90.9

(E) 93.9

[This is a modified version of Question 7 on the Spring 2014 Multiple Choice exam.]

9.5. For a 2-year last survivor term life insurance on two lives each age 30, with independent future lifetimes, you are given:

(i) The insurance pays 10,000 at the end of the year of the second death.

(ii) For each life, $q_{30} = 0.04$ and $q_{31} = 0.06$

(iii) Premiums are payable at the beginning of the year while either life is alive.

(iv) $i = 0.05$

Calculate the annual net premium for this insurance.

(A) 39

(B) 41

(C) 43

(D) 45

(E) 47

[This was Question 11 on the Spring 2014 Multiple Choice exam.]

9.6. For two lives, (60) and (70), with independent future lifetimes, you are given:

(i) $_5p_{60} = 0.92$

(ii) $_5p_{70} = 0.88$

(iii) $1000\,q_{65} = 21.32$

(iv) $1000\,q_{75} = 51.69$

Calculate $1000\;_{5|}q_{\overline{60:70}}$.

(A) 6.3

(B) 6.6

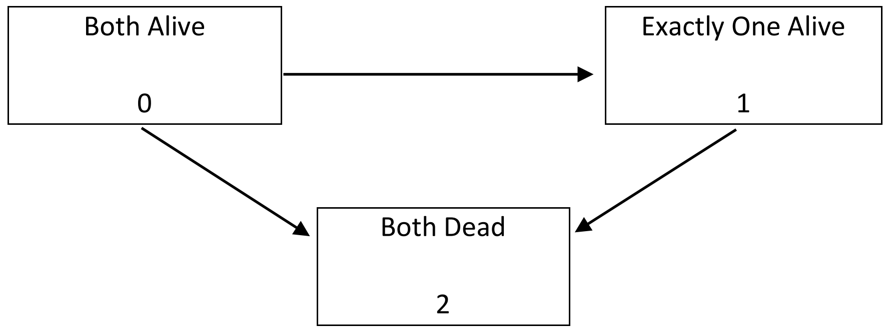
(C) 6.9

(D) 7.2

(E) 7.5

[This was Question 1 on the Fall 2014 Multiple Choice exam.]

9.7. You are using the following multiple state model for the future lifetimes of (30) and (30):



You are given:

(i) $\mu^{01}_{30+t:30+t} = 0.014 + 0.0007 \times 1.075^{(30+t)}, \quad t \geq 0$

(ii) $\mu^{02}_{30+t:30+t} = 0.006, \quad t \geq 0$

Calculate ${}_{10}p^{00}_{30:30}$.

(A) 0.73

(B) 0.75

(C) 0.77

(D) 0.79

(E) 0.81

[This was Question 3 on the Spring 2015 Multiple Choice exam.]

9.8. Bill and Laura, each age 45, with independent future lifetimes, purchase a special life insurance policy with the following provisions:

(i) Premiums are payable annually, at the beginning of the year, for as long as Bill and Laura are both alive.

(ii) The policy pays, at the beginning of the year, 60,000 per year while only Laura is alive.

(iii) The policy pays, at the beginning of the year, 3 times the net premium per year while only Bill is alive.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) $i = 0.05$

Calculate the net premium for this special life insurance policy.

(A) 4065

(B) 4365

(C) 4665

(D) 4965

(E) 5265

[This is a modified version of Question 13 on the Spring 2015 Multiple Choice exam.]

9.9. For a special life insurance policy on Rochelle and Suzanne, both age 50, with independent future lifetimes, you are given:

(i) A death benefit of 30,000 is payable at the end of the year of the first death.

(ii) A death benefit of 70,000 is payable at the end of the year of the second death.

(iii) Mortality follows the Standard Ultimate Life Table.

(iv) $i = 0.05$

Calculate the actuarial present value of this insurance.

(A) 15,526

(B) 16,636

(C) 17,746

(D) 18,856

(E) 19,966

[This is a modified version of Question 6 on the Fall 2015 Multiple Choice exam.]

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

(i) The force of mortality on (50) is $\mu_{50+t} = \dfrac{1}{50-t}$, for $0 \le t < 50$.

(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

[This was Question 6 on the Spring 2013 Multiple Choice exam.]

9.11. For a 10-year term insurance paying a death benefit of 100,000 at the end of the year of the last death of (50) and (60), provided the last death occurs within the 10 years, you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) Future lifetimes are independent.

(iii) $i = 0.05$

Calculate the single net premium.

(A) 77

(B) 107

(C) 137

(D) 167

(E) 197

[This is a modified version of Question 6 on the Spring 2016 Multiple Choice exam.]

9.12. Pat and Mel are both age 40 with independent future lifetimes. They purchase a deferred annuity-due that pays 1,000,000 per year while both are alive, starting at age 75.

You are given:

(i) The net annual premium, *P*, is payable for ten years, but only while both Pat and Mel are alive.

(ii) Mortality follows the Standard Ultimate Life Table.

(iii) $i = 0.05$

Calculate *P*.

(A) 131,000

(B) 136,000

(C) 141,000

(D) 146,000

(E) 151,000

[This is a modified version of Question 9 on the Spring 2017 Multiple Choice exam.]

9.13. Tom and Jo are both age 55 with independent future lifetimes. They purchase a special, fully discrete, 10-year deferred joint and last survivor annuity policy. You are given:

(i) The annuity is payable at the beginning of the year, starting at age 65, as long as at least one individual is alive.

(ii) The benefit is 10,000 per year while both individuals are alive, and is 6,000 per year if only one individual is alive.

(iii) The premium of P per year is paid annually through the deferred period conditional on both individuals surviving.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) $i = 0.05$

Calculate P.

(A) 10,325

(B) 10,475

(C) 10,625

(D) 10,775

(E) 10,925

[This is a modified version of Question 13 on the Spring 2017 Multiple Choice exam.]

9.14. For (x) and (y) with independent future lifetimes, you are given:

(i) $\bar{a}_x = 10.06$

(ii) $\bar{a}_y = 11.95$

(iii) $\bar{a}_{\overline{xy}} = 12.59$

(iv) $\bar{A}_{x\overset{1}{y}} = 0.09$

(v) $\delta = 0.07$

Calculate $\bar{A}_{\overset{1}{x}y}$.

(A) 0.15

(B) 0.20

(C) 0.25

(D) 0.30

(E) 0.35

[This was Question 2 on the Fall 2013 Multiple Choice exam.]

9.15. For two lives, (50) and (60), with independent future lifetimes, you are given:

(i) Mortality follows the Standard Ultimate Life Table.

(ii) $i = 0.05$

Calculate $a_{50:60:\overline{20|}}$.

(A) 11.30

(B) 11.45

(C) 11.60

(D) 11.75

(E) 11.90

[This is a modified version of Question 5 on the Fall 2015 Multiple Choice exam.]

10.1. 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

[This was Question 12 on the Spring 2013 Multiple Choice exam.]

10.2. A new employee is hired at exact age 45, with a starting salary of 50,000. Salary increases occur at the end of each year. Consider the following two pension plans:

1. A defined benefit plan that pays at retirement an annual annuity-due of 1.5% of the final 3-year average salary for each year of service;

2. A defined contribution plan that contributes X % of the employee's salary at the start of each year before retirement and earns 5% per year.

You are given:

(i) $\ddot{a}_{65} = 10.0$

(ii) Salary increases are 5% per year.

(iii) The employee retires at exact age 65.

(iv) The actuarial present value of the defined benefit annuity-due at age 65 is equal to the defined contribution account balance at age 65.

Calculate X.

(A) 11.0

(B) 11.7

(C) 12.3

(D) 13.0

(E) 13.6

[This was Question 20 on the Fall 2013 Multiple Choice exam.]

10.3. Bob, currently exact age 40, joined a defined benefit pension plan at exact age 35. His current salary is 50,000 per year. He will retire at exact age 65.

You are given:

(i) Bob's salary will increase at the rate of 2% each year on his future birthdays.

(ii) The annual retirement benefit is 0.5% of the final three-year average salary for each year of service.

(iii) Bob wants to supplement this annual retirement benefit with benefits provided from a defined contribution plan, so that the total annual benefit is 42,000.

(iv) Retirement benefits will commence at exact age 65 and are payable at the beginning of each year for life.

(v) $\ddot{a}_{65} = 9.9$

Calculate the defined contribution plan accumulation needed at age 65 so that Bob receives his desired annual benefit.

(A) 220,000

(B) 240,000

(C) 260,000

(D) 280,000

(E) 300,000

[This was Question 18 on the Spring 2014 Multiple Choice exam.]

10.4. A pension plan offers a career average retirement benefit where a member will receive, upon retirement at age 65, an annual pension of 2% per year of service of the average annual salary received throughout the member's years of service.

Tom joins the pension plan on July 1, 2014, with a starting salary of 45,000 per year. His salary will increase by 4% each subsequent July 1st. Tom will retire on June 30, 2044.

Calculate the annual pension that Tom will receive at retirement.

(A) 49,500

(B) 50,000

(C) 50,500

(D) 51,000

(E) 51,500

[This was Question 19 on the Spring 2014 Multiple Choice exam.]

10.5. For a career average pension plan with one participant currently exact age 55, you are given:

(i) The annual retirement benefit is 1.75% of total earnings during the participant's years of service. Retirement occurs at age 65. The retirement benefit is payable monthly with the first payment at age 65.

(ii) Current salary after the increase at age 55 is 50,000. Future salary increases will be 3% and will occur on each birthday.

(iii) Total past earnings are 525,000.

(iv) $i = 0.04$

(v) $\ddot{a}_{65}^{(12)} = 12.60$

(vi) Death is the only decrement before age 65.

(vii) ${}_{10}p_{55} = 0.925$

Calculate the actuarial present value at the participant's current age of the annual retirement benefit.

(A) 129,300

(B) 134,800

(C) 140,300

(D) 145,800

(E) 151,300

[This was Question 19 on the Fall 2014 Multiple Choice exam.]

10.6. You are given the following information for John, exact age 30, who just joined a defined benefit pension plan:

(i) The plan provides a retirement pension of 1.6% of final average salary for each year of service. The final average salary is defined as the average salary in the three years before retirement.

(ii) John's salary is currently 40,000 and is expected to increase 3.5% annually on his birthdays.

(iii) John will retire at exact age 65.

Calculate the replacement ratio provided by his pension.

(A) 46%

(B) 48%

(C) 50%

(D) 52%

(E) 54%

[This was Question 19 on the Spring 2015 Multiple Choice exam.]

10.7. Fred and Glenn are identical twins currently age 90.

- Both started working for the same company at age 25.
- Both were paid 120,000 per year at age 59.
- The company gives salary increases of 4800 per year after age 59.

The company has a pension plan that pays a continuous pension benefit as follows:

- The pension benefit is 2% of final one-year salary for each year of service.
- The normal retirement age is 65.
- For retirement before age 65, the pension reduction factor is 4% per year.

Fred retired at exact age 60 and Glenn at exact age 65.

Calculate the age by which they had both received the same total benefits (discounted at 0%).

(A) 71.0

(B) 71.5

(C) 72.0

(D) 72.5

(E) 73.0

[This was Question 20 on the Spring 2015 Multiple Choice exam.]

10.8. For a defined benefit pension plan, you are given:

(i) The retirement benefit is 25 per month for each year of service.

(ii) The normal retirement age is 65.

(iii) Early retirement is allowed beginning at age 63 with the retirement benefit reduced by 7.2% per year prior to age 65.

(iv) Bob is an employee age 50 who was hired at age 30.

(v) $i = 0.07$

(vi) Benefits are valued assuming that retirement (r) is the only decrement from employment.

(vii) Employees retire only on their birthdays.

(viii)

Age x	$q_x^{(r)}$	$\ddot{a}_x^{(12)}$
63	0.4	12.0
64	0.2	11.5
65	1.0	11.0

Calculate the actuarial present value of Bob's retirement benefit.

(A) 16,900

(B) 23,180

(C) 29,470

(D) 35,750

(E) 42,040

[This was Question 18 on the Fall 2015 Multiple Choice exam.]

10.9. A defined benefit pension plan provides its members, upon retirement at age 65, retirement benefits from one of two options:

(i) An annual pension equal to 2% of career average salary for each year of service.

(ii) An annual pension equal to $R\%$ of final average salary for each year of service. Final average salary is defined to be the average salary earned in the 5 years immediately preceding retirement.

Colton joins the pension plan at age 35 and his salary increases by 2.5% each year on his birthday.

Under either option, Colton would receive the same annual pension benefit.

Calculate $R\%$.

(A) 1.1%

(B) 1.3%

(C) 1.5%

(D) 1.7%

(E) 1.9%

[This was Question 19 on the Fall 2015 Multiple Choice exam.]

10.10. A new employee, age 35, has a choice between two pension plans:

Plan I:	The employer makes contributions of 15% of salary each year. Contributions are made at the beginning of each year and earn 3% per year. Accumulated contributions at retirement are used to purchase a monthly life annuity due.
Plan II:	The annual pension benefit is 1.5% of the two-year final average salary for each year of service. These benefits are payable on a monthly basis, at the beginning of each month.

You are given:

(i) $\ddot{a}_{65}^{(12)} = 9.44$

(ii) Annual salary increases by 3% each year on the participant's birthday.

(iii) Retirement occurs at age 65.

Calculate the ratio of the monthly payments under Plan I to those under Plan II.

(A) 0.79

(B) 0.99

(C) 1.05

(D) 1.11

(E) 1.15

[This was Question 20 on the Fall 2015 Multiple Choice exam.]

10.11. Kevin is a participant in a defined benefit pension plan at DMN Pharmaceuticals. You are given:

(i) Kevin was born December 31, 1980.

(ii) Kevin was hired on January 1, 2011 with an annual salary of 35,000.

(iii) Kevin's salary has increased each year on January 1 by 3% in 2012 through 2015.

(iv) The annual accrued benefit as of any date under the pension plan is 2% of the average annual salary over the three years prior to that date multiplied by the number of years of service as of that date. The accrued benefit is payable annually on the first of the month following the participant's birthday, beginning on the first of the month following the 65^{th} birthday.

A valuation is performed as of January 1, 2016 using the Traditional Unit Credit cost method and the following assumptions:

- Kevin's salary will increase by 3% on the valuation date and on each January 1 in the future as long as Kevin remains employed by DMN.
- The retirement assumption is a single decrement of 100% at age 65.
- All other decrements combined equal 5% at July 1 each year before age 65.
- There are no benefits except for retirement benefits.
- $i = 0.04$
- $\ddot{a}_{65} = 11.0$

Calculate the actuarial accrued liability for the retirement decrement under this valuation.

(A) 2770

(B) 2785

(C) 2810

(D) 2835

(E) 2850

10.12. Kevin is a participant in a defined benefit pension plan at DMN Pharmaceuticals. You are given:

(i) Kevin was born December 31, 1980.
(ii) Kevin was hired on January 1, 2011 with an annual salary of 35,000.
(iii) Kevin's salary has increased each year on January 1 by 3% in 2012 through 2015.
(iv) The annual accrued benefit as of any date under the pension plan is 2% of the average annual salary over the three years prior to that date multiplied by the number of years of service as of that date. The accrued benefit is payable annually for retired participants on the first of the month following the participant's birthday, beginning on the first of the month following the 65th birthday.

A valuation is performed as of December 31, 2015 using the Traditional Unit Credit cost method and the following assumptions:

- Kevin's salary will increase by 3% on the valuation date and on each January 1 in the future as long as Kevin remains employed by DMN.
- The retirement assumption is a single decrement of 100% at age 65.
- All other decrements combined equal 5% at July 1 each year before age 65.
- There are no benefits except for retirement benefits.
- $i = 0.04$
- $\ddot{a}_{65} = 11.0$

Calculate the normal cost for the retirement decrement under this valuation.

(A) 600

(B) 620

(C) 640

(D) 660

(E) 680

10.13. Kira is a participant in a defined benefit pension plan at DMN Pharmaceuticals. You are given:

(i) Kira was born December 31, 1980.

(ii) Kira was hired on January 1, 2011 with an annual salary of 35,000.

(iii) Kira's salary has increased each year on January 1 by 3% in 2012 through 2015.

(iv) The annual accrued benefit as of any date under the pension plan is 2% of the 3-year final average salary as of that date multiplied by the number of years of service as of that date. The accrued benefit is payable annually for retired participants on the first of the month following the participant's birthday, beginning on the first of the month following the 65th birthday.

A valuation is performed as of December 31, 2015 using the Projected Unit Credit cost method and the following assumptions:

- Kira's salary will increase by 3% on the valuation date and on each January 1 in the future as long as Kira remains employed by DMN.
- The retirement assumption is a single decrement of 100% at age 65.
- All other decrements combined equal 5% at July 1 each year before age 65.
- There are no benefits except for retirement benefits.
- $i = 0.04$
- $\ddot{a}_{65} = 11.0$

Calculate the actuarial liability for the retirement decrement under this valuation.

(A) 6660

(B) 6760

(C) 6860

(D) 6960

(E) 7060

10.14. Kira is a participant in a defined benefit pension plan at DMN Pharmaceuticals. You are given:

(i) Kira was born December 31, 1980.
(ii) Kira was hired on January 1, 2011 with an annual salary of 35,000.
(iii) Kira's salary has increased each year on January 1 by 3% in 2012 through 2015.
(iv) The annual accrued benefit as of any date under the pension plan is 2% of the 3-year final average salary as of that date multiplied by the number of years of service as of that date. The accrued benefit is payable annually for retired participants on the first of the month following the participant's birthday, beginning on the first of the month following the 65th birthday.

A valuation is performed as of December 31, 2015 using the Projected Unit Credit cost method and the following assumptions:

- Kira's salary will increase by 3% on the valuation date and on each January 1 in the future as long as Kira remains employed by DMN.
- The retirement assumption is a single decrement of 100% at age 65.
- All other decrements combined equal 5% at July 1 each year before age 65.
- There are no benefits except for retirement benefits.
- $i = 0.04$
- $\ddot{a}_{65} = 11.0$

Calculate the normal cost for the retirement decrement under this valuation.

(A) 1050

(B) 1150

(C) 1250

(D) 1350

(E) 1450

10.15. You are given the following information about a 60 year old member of a defined benefit pension plan with 35 years of past service:

(i) S_x denotes the salary earned from age *x* to $x+1$.

(ii) Death is the only decrement other than retirement and occurs mid-year.

(iii) There are no benefits paid upon death.

(iv) ${}_tV$ represents the actuarial liability at age $25+t$.

(v) Funding is based on the projected unit credit method.

Which of the following is a correct expression for the normal contribution for the retirement benefit at the start of the current year?

(A) $\dfrac{1}{60}\,{}_{35}V$

(B) $\left(1-\dfrac{25S_{59}}{26S_{60}}\right){}_{35}V$

(C) $\dfrac{1}{35}\,{}_{35}V$

(D) $\left(\dfrac{26S_{60}}{25S_{59}}-1\right){}_{35}V$

(E) $\dfrac{1}{25}\,{}_{35}V$

[This was Question 18 on the Spring 2016 Multiple Choice exam.]

10.16. A pension plan provides an annual retirement benefit of 2% of final year's salary for each year of service, payable at the start of each month, upon retirement at age 65. The annual retirement benefit cannot exceed 60% of final year's salary.

A member, now age 45, joined the plan at age 30. Her current salary is 50,000 and will increase at the rate of 3% per year at the start of each year in the future.

You are given:

(i) $l_{45}^{(\tau)} = 5000$ and $l_{65}^{(\tau)} = 3000$

(ii) $i = 0.05$

(iii) $\ddot{a}_{65}^{(12)} = 7.80$

Calculate the expected present value of this member's retirement benefit.

(A) 93,000

(B) 101,000

(C) 109,000

(D) 260,000

(E) 411,000

[This was Question 19 on the Spring 2016 Multiple Choice exam.]

10.17. Phillip, who is age 40, joins XYZ company which offers him a choice of two pension plans:

- Plan 1 pays an annual pension of 1250 for each year of service.
- Plan 2 pays an annual pension of 2% of his career average salary for each year of service.

You are given:

(i) His starting salary is S_0 and he will receive a 4% salary increase at the beginning of each year starting at age 41.

(ii) He will retire at age 65.

(iii) Plan 1 and Plan 2 both pay benefits at the beginning of each year.

(iv) Plan 1 and Plan 2 yield the same replacement ratio for him.

Calculate S_0

(A) 27,500

(B) 30,000

(C) 32,500

(D) 35,000

(E) 37,500

[This was Question 20 on the Spring 2016 Multiple Choice exam.]

10.18. For a member of a defined contribution plan who is age 65, you are given:

(i) The member's current salary is 250,000, and there will be no future salary increases.

(ii) The member's current retirement fund is 1,500,000 and there are no expected future contributions prior to retirement.

(iii) The retirement fund grows at a rate of 8% annually.

(iv) Upon retirement, the member will use her retirement fund as the single net premium for an annuity due that makes quarterly payments.

(v) The single net premium is calculated using the Standard Ultimate Life Table and $i = 0.05$.

Calculate, using the 2-term Woolhouse approximation, the member's replacement ratio upon retirement at age 66.

(A) 0.30

(B) 0.35

(C) 0.40

(D) 0.45

(E) 0.50

[This is a modified version of Question 18 on the Fall 2016 Multiple Choice exam.]

10.19. Tim is a member of a defined benefit pension plan that provides its members, upon retirement at age 65, an annual pension payable monthly in advance equal to 2% of final salary per year of service. Final salary is defined to be the salary earned in the year immediately preceding retirement.

Tim's salary throughout 2015 was 150,000, and he will not receive a salary increase in 2016. However, his salary will increase by 2% every January 1, starting at
January 1, 2017.

On the valuation date, January 1, 2016, Tim is age 45 with 10 years of past service.

You are given:

(i) $i = 5\%$

(ii) ${}_t p_{45}^{(\tau)} = 0.99^t$, for $t \le 20$

(iii) $\ddot{a}_{65}^{(12)} = 13.75$

(iv) There are no benefits other than retirement benefits.

Calculate the normal contribution for Tim on the valuation date assuming a traditional unit credit funding method.

(A) 12,700

(B) 14,000

(C) 16,500

(D) 18,900

(E) 20,800

[This was Question 19 on the Fall 2016 Multiple Choice exam.]

10.20. Kaitlyn entered a defined benefit plan on January 1, 1990 with a salary for 1990 of 50,000. You are given:

(i) The annual retirement benefit is 2% of the final 5-year average salary for each year of service.

(ii) Her normal retirement date is December 31, 2023.

(iii) The reduction in benefit for early retirement is 7% for each year prior to her normal retirement date.

(iv) Every January 1, each employee receives a 2.5% increase in salary.

(v) Kaitlyn retires on December 31, 2020.

Calculate Kaitlyn's annual retirement benefit.

(A) 45,200

(B) 46,100

(C) 47,000

(D) 48,900

(E) 50,000

[This was Question 20 on the Fall 2016 Multiple Choice exam.]

10.21. Tom, who is age 50 today, is a participant in a pension plan with the following supplemental benefits payable at retirement:

Age at Retirement	Lump Sum Supplemental Benefit
62	20,000
63	25,000
64	30,000

Supplemental benefits are not provided at any other ages.

You are given the following assumptions:

(i) Retirements at 62, 63, and 64 take place in the middle of the year of age.

(ii) Decrements for this pension plan follow the Standard Service Table.

(iii) $i = 0.05$

Calculate the actuarial present value of Tom's supplemental benefits.

(A) 1480

(B) 1530

(C) 1580

(D) 1630

(E) 1680

[This is a modified version of Question 18 on the Spring 2017 Multiple Choice exam.]

10.22. A defined benefit pension plan provides its members, upon retirement at age 65, an annual pension equal to 2% of final salary per year of service. Final salary is defined to be the salary earned in the calendar year immediately preceding retirement. The pension benefit will be paid in the form of a life annuity payable at the beginning of each month.

Justin joined the pension plan at exact age 30 on January 1, 2002 with a salary of 63,000. He expected this salary to increase by 5% each year on his birthday. As of January 1, 2017, Justin's annual salary has always increased at that rate.

You are given: $\ddot{a}_{65}^{(12)} = 11$ and ${}_{20}E_{45} = 0.15$

Calculate the actuarial accrued liability on January 1, 2017, of Justin's retirement benefit using the Traditional Unit Credit method.

(A) 62,000

(B) 65,000

(C) 156,000

(D) 164,000

(E) 172,000

[This was Question 19 on the Spring 2017 Multiple Choice exam.]

10.23. On January 1, 2017, Louis is a 51 year old member of a defined benefit pension plan. Louis has 10 years of past service and his salary for 2017 is 70,400. You are given:

(i) The annual retirement benefit is 2% of the final year's salary for each year of service. There are no death benefits.

(ii) His salary for 2016 was 68,700.

(iii) The pension is payable as a monthly single life annuity-due upon retirement.

(iv) His normal retirement date is December 31, 2030 at age 65. There are no decrements other than death prior to retirement.

(v) Mortality follows the Standard Ultimate Life Table.

(vi) $i = 0.05$

(vii) $\ddot{a}_{65}^{(12)} = 13.0915$

Calculate the normal contribution at January 1, 2017 under the Traditional Unit Credit cost method.

(A) 11,100

(B) 12,100

(C) 13,100

(D) 14,100

(E) 15,100

[This is a modified version of Question 20 on the Spring 2017 Multiple Choice exam.]

10.24. Julie, age 45, is a participant in a defined benefit pension plan at DMN Widgets. You are given:

(i) She has 15 years of service.

(ii) Her salary for the past year was 120,000.

(iii) She will receive salary increases of 4% annually with the first increase tomorrow.

(iv) Her retirement benefit, payable annually at the start of the year, is 1.5% of her final year's salary, for each year of service.

(v) She can only retire in 20 years, at age 65.

(vi) She will not receive any benefits if she leaves prior to retirement.

(vii) ${}_{20}p_{45}^{(\tau)} = 0.552$

(viii) $i = 0.05$

(ix) $\ddot{a}_{65} = 10.60$

Using the projected unit credit funding method, calculate the normal cost for Julie's retirement benefits for the next year.

(A) 7900

(B) 8100

(C) 8300

(D) 8500

(E) 8700

[This was Question 20 on the Fall 2017 Multiple Choice exam.]

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

(i) Reserves are net premium reserves based on the Standard Ultimate Life Table and 5% 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) 210

(B) 220

(C) 230

(D) 240

(E) 250

[This is a modified version of Question 17 on the Spring 2013 Multiple Choice exam.]

12.2 An insurer issues identical fully discrete 10-year term insurance policies of 100,000 to independent lives, all age 60. The annual premium is 1500 for each policy.

You are given the following profit test assumptions:

- For each policy, expenses of 100 are incurred at the beginning of each of the first 2 years.
- $q_{60} = 0.010, \quad q_{61} = 0.012$
- The reserve for a policy in force at the end of the first year is 400, and for a policy in force at the end of the second year is 700.
- $i = 0.072$

Calculate the expected profit emerging at the end of the second year, per policy in force at the start of the second year.

(A) 30

(B) 38

(C) 46

(D) 54

(E) 62

[This was Question 17 on the Spring 2014 Multiple Choice exam.]

12.3. For a fully discrete 2-year term life insurance on (50), you are given:

(i) Cash flows are annual.

(ii) The annual gross premium is 250.

(iii) The annual hurdle rate used for profit calculations is 10%.

(iv) The profit vector is (−165, 100, 125).

(v) The profit margin for this insurance is 6%.

Calculate the probability that (50) will survive one year.

(A) 0.95

(B) 0.96

(C) 0.97

(D) 0.98

(E) 0.99

[This was Question 15 on the Spring 2015 Multiple Choice exam.]

12.4. For a fully discrete 3-year term life insurance policy on (40) you are given:

(i) All cash flows are annual.

(ii) The annual gross premium is 1000.

(iii) Profits and premiums are discounted at an annual effective interest rate of 12%.

(iv) The profit vector:

Time in years	Profit
0	-400
1	150
2	274
3	395

(v) The profit signature:

Time in years	Profit
0	-400
1	150
2	245
3	300

Calculate the profit margin.

(A) 4.9%

(B) 5.3%

(C) 5.9%

(D) 6.6%

(E) 9.7%

12.5. For a 5-year term insurance policy on (x), you are given:

(i) The profit signature is $\Pi = \{-550, 300, 275, 75, 150, 100\}$

(ii) The risk discount rate is 12%.

Calculate the discounted payback period (DPP) for this policy.

(A) 1

(B) 2

(C) 3

(D) 4

(E) 5

[This was Question 15 on the Fall 2016 Multiple Choice exam.]

12.6. You are conducting a profit test on a fully discrete 3-year term insurance policy of 1000 issued to (55). Some details of your profit test calculations are summarized below.

Policy Year k	Starting Reserve	Gross Premium	Expenses	Investment Earnings	Expected Death Benefit	Expected Cost of Reserve	q_{55+k-1}
1	0	75	20	2.80	10.00	64.35	0.010
2	65	75	20	6.00	15.00	123.13	0.015
3	125	75	20	9.00	21.00	0.00	0.021

You are also given:

(i) The pre-contract expenses are 100.

(ii) There are no lapses.

(iii) The hurdle rate is 10%.

Calculate the net present value of this policy.

(A) -2.5

(B) -1.9

(C) 0

(D) 1.9

(E) 2.5

[This was Question 17 on the Spring 2017 Multiple Choice exam.]

LM.1. An employer is modelling time to retirement of workers using the Kaplan-Meier estimator. You are given the following information.

(i) There are 1000 workers in force at time 0.

(ii) At time 10, there are 600 workers remaining.

(iii) The Kaplan-Meier estimate of the survival function for retirement at time 10 is $\hat{S}_{1000}(10) = 0.8$

(iv) The next retirement after time 10 occurred at time 12, when 100 workers retired.

(v) During the period from time 10 to time 12, a total of 200 workers dropped out for various other reasons.

Calculate $\hat{S}_{1000}(12)$, the Kaplan-Meier estimate of the survival function $S(12)$.

(A) 0.40

(B) 0.45

(C) 0.50

(D) 0.55

(E) 0.60

LM.2. In a study of 1,000 people with a particular illness, 200 died within one year of diagnosis. Calculate a 95% (linear) confidence interval for the one-year empirical survival function.

(A) (0.745, 0.855)

(B) (0.755, 0.845)

(C) (0.765, 0.835)

(D) (0.775, 0.825)

(E) (0.785, 0.815)

LM.3. A cohort of 100 newborns is observed from birth. During the first year, 10 drop out of the study and one dies at time 1. Eight more drop out during the next six months, then, at time 1.5, three deaths occur.

Compute the Nelson-Åalen estimator of the survival function, $S(1.5)$.

(A) 0.950

(B) 0.951

(C) 0.952

(D) 0.953

(E) 0.954

LM.4. You are given the following data based on 60 observations:

i	y_i	s_i	b_i
1	5	5	7
2	8	6	7
3	13	7	7
4	16	6	5
5	21	6	4

Calculate the upper limit of the 80% confidence interval for $S(21)$ using the Kaplan-Meier estimate and Greenwood's approximation.

(A) 0.249

(B) 0.283

(C) 0.311

(D) 0.335

(E) 0.351

LM.5. In a study of workplace retention for a large employer, the following grouped data were collected from 100 new entrants.

Time to exit	Number of employees
0 – 5 years	28
5 – 10 years	19
10 – 20 years	15
20 – 30 years	30
Over 30 years	8

Calculate the probability that an employee exits within the first 12 years, using the ogive empirical distribution function.

(A) 0.49

(B) 0.50

(C) 0.51

(D) 0.52

(E) 0.53

LM.6. Assume the Markov model of unemployment illustrated in the following diagram. Transition intensities are assumed to be constant for the lives under consideration.

In a study of 5 lives, over a one-year observation period, you are given the following information.

- 3 lives remained employed throughout
- 1 life became unemployed at $t = 0.35$ and became employed again at $t = 0.75$
- 1 life became unemployed at $t = 0.45$ and remained unemployed for the rest of the year.

Calculate an estimate of the standard deviation of the maximum likelihood estimator, $\hat{\mu}_x^{01}$.

(A) 0.22

(B) 0.28

(C) 0.35

(D) 0.42

(E) 0.50

S1.1. Alice purchases a disability income insurance on January1, 2018, which pays a monthly benefit during eligible periods of sickness. The policy will expire on December31, 2025. The benefit payment term is 1 year. The waiting period is 2 months and the off period is 4 months.

Alice becomes sick on July 1, 2018. She recovers and returns to work on December 1, 2018. On March 1, 2019, she becomes sick again, until she returns to work on November 1, 2019. She remains in work until the end of 2019.

How many months of sickness benefit are paid under the policy in the period January 1, 2018 to December 31, 2019?

(A) 9

(B) 10

(C) 11

(D) 12

(E) 13

S2.1. In the Standard Sickness-Death Model, you are given:

(i) $i = 0.05$

(ii) $\ddot{a}_{50}^{01} = 1.9618$; $\ddot{a}_{60}^{01} = 2.6283$; $\ddot{a}_{60}^{11} = 10.7144$

Calculate 10,000 $a_{50:\overline{10}|}^{01}$.

(A) 1766

(B) 1966

(C) 2166

(D) 2366

(E) 2566

S3.1. A disability income insurance policy pays 30,000 at the end of each year to (50), conditional on the policyholder being sick at that time. The annual premium, *P*, is payable at the start of each year conditional on the policyholder being healthy. The policy ceases after 20 years.

You are given:

(i) The benefits are valued using the Standard Sickness-Death Model.

(ii) $i = 0.06$

(iii) Expenses of 5% of premium are incurred with each premium payment.

(iv) Expenses of 5% of benefits are incurred with each benefit payment.

(v) $P = 2360$

(vi) $p_{60}^{00} = 0.97026; \quad p_{60}^{01} = 0.01467; \quad p_{60}^{10} = 0.00313; \quad p_{60}^{11} = 0.97590$

(vii) ${}_{10}V^{(0)} = 5946; \quad {}_{10}V^{(1)} = 200,640$

Calculate ${}_{11}V^{(0)}$

(A) 5550

(B) 5650

(C) 5750

(D) 5850

(E) 5950

S4.1. Improving maintenance protocols will extend the lifetime of a type of industrial robot. The robot's mortality rates and improvement factors are given below:

x	$q(x,0)$	$\varphi(x,1)$	$\varphi(x,2)$
0	0.4	0.10	0.08
1	0.5	0.08	0.06
2	0.6	0.06	0.04

Calculate the probability that a robot placed into service today is still functioning at the end of three years.

(A) 0.13

(B) 0.14

(C) 0.15

(D) 0.16

(E) 0.17

S4.2. The actuarial profession in the (fictional) country of Avondale has set short term improvement factors for population mortality based on the experience in 2016 and 2017, and long term factors based on projected values in 2027 and 2028. Actuaries are to calculate the appropriate improvement factors for intermediate years using a cubic spline. You are given the following information:

(i) There are no cohort effects in Avondale population mortality.

(ii) $\varphi(35,2016)=0.035 \quad \varphi(35,2017)=0.037$

(iii) $\varphi(35,2027)=0.015 \quad \varphi(35,2028)=0.015$

Calculate the improvement factor applying to a life age 35 in 2022.

(A) 0.0255

(B) 0.0265

(C) 0.0275

(D) 0.0285

(E) 0.0295

S4.3. You are given the following parameters for a Lee-Carter model:

$$\alpha_{60} = -4.0 \quad \beta_{60} = 0.25 \quad K_{2018} = -3.0 \quad c = -0.05 \quad \sigma_K = 0.9$$

Calculate the expected value of $m(60, 2020)$.

(A) 0.0083

(B) 0.0085

(C) 0.0087

(D) 0.0089

(E) 0.0091

S4.4. You are given the following parameters for a Lee-Carter model:

$$\alpha_{60} = -4.0 \quad \beta_{60} = 0.25 \quad K_{2018} = -3.0 \quad c = -0.05 \quad \sigma_K = 0.9$$

Calculate the standard deviation of $m(60, 2020)$

(A) 0.0029

(B) 0.0031

(C) 0.0033

(D) 0.0035

(E) 0.0037

S4.5. You are given the following parameters for a Lee-Carter model:

$$\alpha_{60} = -4.0 \quad \beta_{60} = 0.25 \quad K_{2018} = -3.0 \quad c = -0.05 \quad \sigma_K = 0.9$$

Calculate the 95% quantile of $m(60, 2020)$.

(A) 0.010

(B) 0.014

(C) 0.018

(D) 0.022

(E) 0.026

S4.6. You are given the following parameters for a Lee-Carter model:

$$\alpha_{60} = -4.0 \quad \beta_{60} = 0.25 \quad K_{2018} = -3.0 \quad c = -0.05 \quad \sigma_K = 0.9$$

Under this model, $lm(60, 2020)$ is distributed as a normal distribution with a mean of -4.775 and a variance of 0.10125 .

Calculate the 95% quantile of $p(60, 2020)$ assuming uniform distribution of deaths between integer ages.

(A) 0.985

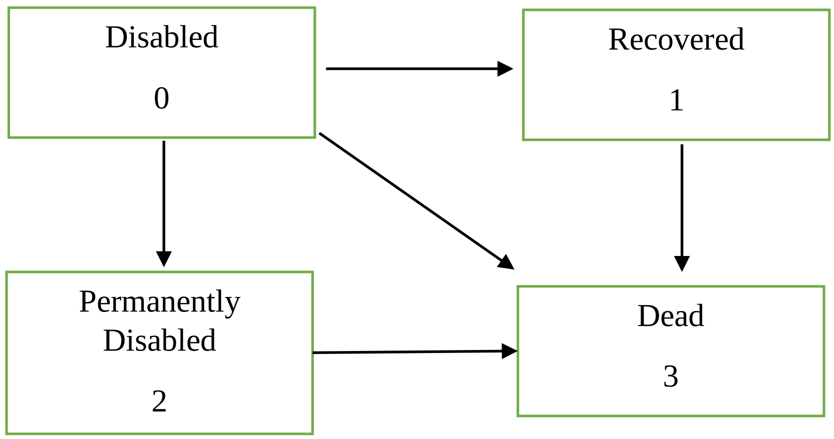
(B) 0.989

(C) 0.991

(D) 0.993

(E) 0.995

S5.1. You are given the following multiple state model for structured settlements.



You are also given

(i) $\bar{a}_x^{00} = 0.520, \quad \bar{a}_x^{01} = 3.24, \quad \bar{a}_x^{02} = 5.60, \quad \bar{a}_x^{11} = 17.37, \quad \bar{a}_x^{22} = 7.90$

(ii) $\delta = 0.04$

Calculate $10,000\bar{A}_x^{03}$

(A) 6256

(B) 6356

(C) 6456

(D) 6556

(E) 6656

S6.1. You are given the following information about a post-retirement health benefit plan:

(i) $B(x,t)$ denotes the annual supplementary health insurance premium for a life age x at t

(ii) For $k > 0$, $B(x+k,t) = (1.03)^k B(x,t)$

(iii) Premium inflation at all ages is 4% per year.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) $i = 0.06$

(vi) $\ddot{a}_B(65,2) = 26.708$

Calculate $\ddot{a}_B(63,2)$

(A) 25.0

(B) 26.0

(C) 27.0

(D) 28.0

(E) 29.0

S6.2. For a post-retirement health benefit, you are given the following information.

(i) The current health care premium at age 60 is 5000.

(ii) The premium is assumed to increase each year with a rate of health inflation of $j = 0.03$

(iii) The premium is also assumed to increase for each year of age by a factor of $c = 1.0194$.

(iv) Mortality follows the Standard Ultimate Life Table.

(v) One-half of the lives reaching age 60 retire at that time. The remainder retire at exact age 61.

(vi) There are no exits before retirement other than mortality

(vii) Assume linear accrual of the health care benefit to the retirement age.

(viii) $i = 0.05$

(ix) $e_{60} = 26.71 \qquad e_{61} = 25.80$

Calculate the normal cost for this benefit for a life currently age 50 with 20 years of service.

(A) 3480

(B) 3610

(C) 3735

(D) 3870

(E) 3990