INSTITUTE OF ACTUARIES OF INDIA

EXAMINATIONS

November 2025

CM1 - Actuarial Mathematics for Modelling (Paper A)

Time allowed: 3 Hours 15 Minutes

Total Marks: 100

Instructions:

- State any assumptions made clearly.
- Unless stated otherwise, interest rates are annual effective and payments occur at the end of each year.
- Express monetary amounts in ₹ and percentages to two decimal places.
- Use standard actuarial notation as per the CM1A syllabus.
- Marks are awarded for method and reasoning as well as accuracy.
- Ensure the work presented is entirely your own.

Q.1) FinSure Ltd. invests ₹2,00,000 in a 3-year fixed deposit convertible quarterly at a nominal rate of 7.8% p.a. What is the equivalent annual effective rate of return? **[2]**

A. 7.80%
B. 7.92%
C. 8.00%
D. 8.03%
E. 8.12%

Q.2) Which of the following relationships is correct? **[2]**

A. i = d/(1-d)
B. i = d(1-d)
C. d = i/(1-i)
D. i = d/(1+d)
E. i = (1-d)^2 - 1

Q.3) A growing Immediate-perpetuity pays ₹1,000 at the end of first year. Annuity payments increase at a compound rate of 2% per annum thereafter.

If the effective annual rate of interest is 5%, find the present value of annuity (to the nearest ₹1,000). **[2]**

A. ₹32,000
B. ₹33,000
C. ₹35,000
D. ₹36,000
E. ₹38,000

Q.4) CapitalPlus Ltd. considers a project costing ₹50,000 today with cash inflows of ₹15,000 per year at the end of each year for the first four years and ₹10,000 at the end of 5th year. Calculate Net Present Value (NPV) of the project at 6% effective rate of interest. **[2]**

A. ₹7,400
B. ₹7,885
C. ₹8,264
D. ₹8,450
E. ₹9,449

Q.5) A loan of ₹60,000 is repaid by quarterly instalments over 6 years at 9% p.a. effective rate of interest. Find level quarterly instalment (nearest), assuming payments are made at the end of each quarter. **[2]**

A. ₹4,539
B. ₹4,200
C. ₹3,375
D. ₹4,543
E. ₹3,236

Q.6) A 3-year project has cashflows: −₹10,000 now, +₹4,000, +₹4,500, +₹5,500. Find the approximate internal rate of return (IRR). **[2]**

A. 8.9%
B. 9.6%
C. 13.5%
D. 11.9%
E. 17.8%

Q.7) In a multiple decrement model, two causes of exit have constant forces: $\mu_x(1)=0.02$, $\mu_x(2)=0.03$. Find the total annual probability of exits(upto four decimal places). **[2]**

A. 0.0488
B. 0.0460
C. 0.0494
D. 0.0500
E. 0.0510

Q.8) Two lives aged 40 (x) and 45 (y) have independent one-year survival probabilities of 0.97 and 0.95. Find the probability that at least one survives one year. **[2]**

A. 0.9215
B. 0.9500
C. 0.9990
D. 0.9985
E. 0.9980

Q.9) In a multiple decrement model, total $q_x = 0.05$. If cause 1 accounts for 60% of total exits and cause 2 for 40%, find the dependent probabilities $q_x(1)$ and $q_x(2)$, assuming uniform distribution of decrements. **[2]**

A. (0.03, 0.02)
B. (0.029, 0.021)
C. (0.031, 0.019)
D. (0.032, 0.018)
E. (0.033, 0.017)

Q.10) A 3-year term assurance policy provides a sum assured of ₹100,000, with level annual premiums payable in advance.

Assume:
Effective annual interest rate $i = 5\ \%$
Constant annual mortality rate $q = 0.01$
Annual premium $P =$ ₹ 952
Calculate the prospective reserve per policy in force at the start of the third year.

[2]

A. ₹941
B. ₹952
C. ₹933
D. ₹960
E. ₹975

Q.11) A 5-year term assurance policy, SA ₹100,000 payable at the end of the year of death, $q_x=0.01$, i=6%. Find the net single premium. **[2]**

A. ₹4,133
B. ₹4,525
C. ₹4,650
D. ₹4,700
E. ₹4,891

Q.12) A life insurer performs a profit test for a 4-year unit-linked endowment assurance and obtains the following expected non-unit cashflows (₹ per policy) at the end of each year:

(−500, −200, +150, +400)

The annual effective rate of interest is 5%. Ignore mortality. Non-unit reserves are to be held to zeroise all future negative cashflows except any occurring in the first policy year. Interest is earned on non-unit reserves at the same rate. What is the non-unit reserve required at the end of policy year 1 (rounded to the nearest value)? **[2]**

A. 190
B. 285
C. 315
D. 370
E. 410

Q.13) An insurer has a liability of ₹500,000 with liability duration of 4 years. It invests in two zero-coupon bonds: Bond A (2-year) Bond B (6-year) Both yield 5% effective. If the present value of the liability = ₹411,355, determine the ratio of investment in Bond A to Bond B to achieve Redington immunisation. **[2]**

A. 1.000 : 1 ,
B. 1.263 : 1 ,
C. 0.823 : 1,
D. 0.667 : 1 ,
E. 1.500 : 1

Q.14) Reserve recursion: V_2=400, P=1,000, SA=5,000, q=0.02, i=6%. Find V_3. Assume death benefits are payable at the end of the year of death; reserves are measured immediately after annual premium payments. **[2]**

A. ₹1,340
B. ₹1,354
C. ₹1,360
D. ₹1,380
E. ₹1,412

Q.15) If valuation interest < premium basis interest, the reserve will be: **[2]**

A. Higher
B. Lower
C. Unchanged
D. Negative
E. Zero

Q.16) The treasury team of FinSure Capital Ltd. plans to invest ₹5,00,000 for 5 years at 6% effective. Inflation is expected at 3% for the first 3 years, rising to 4% thereafter.

i) Derive the relationship between nominal, real, and inflation rates. (1)

ii) Compute the real rate of interest in both periods. (1)

iii) Determine the real accumulated value after 5 years. (1)

iv) Comment on the impact of inflation variability on long-term investment policy. (2)

EcoInvest, a sustainable asset management firm, is evaluating a 3-year project and wants to estimate future borrowing costs.

They have derived the following annual effective spot rates from the government bond market:

Term (years)	Spot rate
1	4.8%
2	5.4%
3	6.1%

v) Calculate the one-year forward rate implied by the market for borrowing during year 3 (i.e., between the end of year 2 and year 3). (2)

vi) Using these spot rates, find the price of a 3-year 6% annual coupon bond (face value ₹100). (2)

vii) Based on your results, comment on how the market's forward rate structure might influence EcoInvest's view of future interest rate movements. (1)

[10]

Q.17) A 5-year corporate bond pays 8% annual coupons on face value ₹1,00,000, redeemable at par. Market yield = 9%.

i) Derive the equation of value and compute the bond price. (4)

ii) Calculate Macaulay duration and modified duration. (4)

iii) Estimate price change if yield rises by 0.5%. (2)

[10]

Q.18) ActuSure Insurance is pricing a 3-year joint life term assurance for corporate clients. The product pays the sum assured (SA) at the end of the year of the first death among the two lives (i.e. first-death benefit). There are no other benefits.

Consider the joint life of a **male aged 40** and a **female aged 38**. Assume **independence** of lives and **constant forces of mortality** for the 3-year period. The constant forces are:

- Male (age 40): $\mu_m = 0.030$ per annum.
- Female (age 38): $\mu_f = 0.025$ per annum.

Interest rate $i = 7.5$ p.a. (annual effective). Sum Assured SA=₹250,000.

i) Derive an expression for the net single premium (NSP) — i.e. the expected present value of the benefit, NSP - in terms of the forces μ_m, μ_f, interest i and term 3. (3)

ii) Using the numbers above, compute the NSP numerically (show full working; give answer to the nearest rupee). (5)

iii) Briefly comment on the pricing effect if the assumption of independence is replaced by positive dependence between the two lives (e.g. common lifestyle risk). (2)

[10]

Q.19) Sinsurity Insurance plans to launch a 10-year endowment assurance for employees under a group scheme. Sum assured ₹2,00,000, payable at the end of the year of death or maturity. Premiums are payable annual

in advance. Entry to the plan is at age 30 after selection. Basis: AM92 Select, at effective interest rate of 6%.

i) State the equivalence principle. (1)

ii) Derive and compute the annual premium. (7)

iii) Suggest two practical pricing adjustments for expenses and profit loadings. (2)

[10]

Q.20) The Life Division of Raven Insurance monitors solvency under interest rate changes. A 5-year term assurance, SA ₹1,00,000 payable at the end of year of death, premium ₹580 p.a. payable in advance. At start of year 3: valuation interest rate i = 5%, q = 0.004 for all ages.

i) Define prospective and retrospective reserves; when are they equal? (2)

ii) Compute the prospective reserve at 5% at the start of the 3rd year immediately after payment of the 3rd premium. (6)

iii) Explain how lower valuation interest rates would affect a company's solvency margins. (2)

[10]

Q.21) The Corporate Strategy Unit of GreenLife Insurance Ltd. is evaluating a 5-year renewable endowment linked to Environment Social Governance (ESG) investments. Initial capital outflow at time 0 is ₹10 crore. Projected net inflows (₹ crore) at the end of each year is as follows +1.5, +2.0, +2.5, +3.0, +3.5; residual = ₹1.0 crore at end of year 5. Cost of capital = 8%.

i) Calculate:

a) NPV, (2)

b) Payback period (1 mark), and (1)

c) Discounted Payback Period (years, 1 decimal) (2)

ii) Estimate IRR by interpolation (nearest 0.5%). (2)

Due to change in the market conditions, ColdInv a boutique investment firm decides to purchase the block of GreenLife's ESG investment for 5Cr. They plan to finance this investment through a loan for 7 years at nominal rate of 7% p.a. convertible quarterly. The instalments will be paid quarterly in advance, with first payment starting after 18 months.

iii) Calculate the first installment. (3)

iv) Calculate the loan schedule for the 3rd year. (5)

v) if they decide to repay the entire loan at the end of 5th year, what will be the amount they will have to pay, at the end of the quarter after interest. (1)

vi) Explain how profit testing supports product pricing and capital allocation decisions. (2)

vii) Recommend whether to proceed, citing two qualitative business factors (e.g. sustainability, brand impact). (2)

[20]

****