INSTRUCTIONS TO CANDIDATES

General Instructions

1. This examination has a total of 80 points.

   This exam consists of 7 questions, numbered 1 through 7.

   The points for each question are indicated at the beginning of the question. Questions 4 and 5 pertain to the Case Study and questions 6 and 7 pertain to the Case Study and/or extension readings. The Case Study is enclosed inside the front cover of this exam booklet.

2. Failure to stop writing after time is called will result in the disqualification of your answers or further disciplinary action.

3. While every attempt is made to avoid defective questions, sometimes they do occur. If you believe a question is defective, the supervisor or proctor cannot give you any guidance beyond the instructions on the exam booklet.

Written-Answer Instructions

1. Write your candidate number at the top of each sheet. Your name must not appear.

2. Write on only one side of a sheet. Start each question on a fresh sheet. On each sheet, write the number of the question that you are answering. Do not answer more than one question on a single sheet.

3. The answer should be confined to the question as set.

4. When you are asked to calculate, show all your work including any applicable formulas.

5. When you finish, insert all your written-answer sheets into the Essay Answer Envelope. Be sure to hand in all your answer sheets because they cannot be accepted later. Seal the envelope and write your candidate number in the space provided on the outside of the envelope. Check the appropriate box to indicate Exam ERM-INV.

6. Be sure your written-answer envelope is signed because if it is not, your examination will not be graded.

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Tournez le cahier d’examen pour la version française.
CASE STUDY INSTRUCTIONS

The case study will be used as a basis for some examination questions. Be sure to answer the question asked by referring to the case study. For example, when asked for advantages of a particular plan design to a company referenced in the case study, your response should be limited to that company. Other advantages should not be listed, as they are extraneous to the question and will result in no additional credit. Further, if they conflict with the applicable advantages, no credit will be given.
1. (8 points) Basic Assurance (BA) is an insurance company with three major product lines:

**Level Term Life** – This product is a basic term life insurance plan with a level death benefit. Customers can purchase a term period of 10, 20, or 30 years. The total face amount of policies in force is $120 billion. Contracts are reinsured on a 90% YRT (yearly renewable term) basis.

**Fixed Deferred Annuities** – This product allows contract holders to make flexible deposits into an account that is credited interest at an annual rate of 2%. The block has no surrender charges. BA does not reinsure or perform any hedging on this product.

**Medical Stop Loss** – This product pays an annual benefit to employers who self-insure their group medical plans. If an employer experiences annual losses \( L \), in excess of a retention limit \( R \), the product will pay a benefit of \( L - R \) at the end of the year. Coverage can be purchased for up to five years. Company experience data is limited, but sales have been very strong. BA is concerned with employers incurring losses well in excess of their retention limit.

BA measures the economic value of its liabilities separately for each line of business. Economic reserves are set equal to an estimate of the mean loss. A description of the methods and risk metrics used for setting economic capital are shown in the table below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Risk Metric</th>
<th>Year End 2018 Model Output (in $ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level Term Life</td>
<td>Conditional Tail Expectation (CTE) at the 95th percentile</td>
<td>Mean Simulated Loss = $9,000 Maximum Simulated Loss = $11,500 CTE 95 = $10,660</td>
</tr>
<tr>
<td>Fixed Deferred Annuities</td>
<td>Value at Risk (VaR) at the 95th percentile</td>
<td>Mean Simulated Loss = $3,900 Maximum Simulated Loss = $9,900 VaR 95 = $5,400</td>
</tr>
<tr>
<td>Medical Stop Loss</td>
<td>98th Percentile of the Generalized Pareto Distribution (GPD)</td>
<td>Estimated Mean Loss = $500 Model Output to Be Determined</td>
</tr>
</tbody>
</table>

(a) (1.5 points) BA plans to use the 98th percentile of the GPD to calculate its liability exposure on its Medical Stop Loss business. Potential shape parameters of 2.5, 0, and -2.5 have been identified. The distribution function for each is shown below when the scale parameter is equal to 1.
1. Continued

(i) Explain why the GPD is an important distribution in the context of Extreme Value Theory.

(ii) Match the appropriate shape parameters of 2.5, 0, and -2.5 to each of the functions A, B and C in the figure above. Justify your identification for each curve.

(b) (1.5 point) The GPD CDF is as follows:

\[
G(x) = \Pr(X - u \leq x \mid X > u) = \frac{F(x + u) - F(u)}{1 - F(u)}
\]

\[
= \begin{cases} 
1 - \left(1 + \frac{x}{\beta \gamma}\right)^{-\gamma} & \text{if } \gamma \neq 0 \\
1 - \frac{x}{\theta} & \text{if } \gamma = 0 
\end{cases}
\]

(i) Select the most appropriate shape parameter for the Medical Stop Loss business from part (a)(ii). Justify your choice.

(ii) Calculate the 98th percentile of losses in excess of the threshold for the Medical Stop Loss business using the shape parameter from part (i), and a scale parameter of $500 million.

Question 1 continued on the next page
1. **Continued**

(c) *(3 points)* Critique BA’s risk metric choice for each line of business.

(d) *(2 points)* BA’s ERM committee would like to mitigate tail risk arising from the following uncertainties:

- Higher than expected medical losses
- Unanticipated changes in interest rates
- Pandemic mortality risk

Propose a mitigating strategy that BA could implement to address each uncertainty. Justify your proposal.
2. (13 points) Atria is a group insurance company that primarily sells medical and dental insurance and a small amount of LTC insurance. Atria’s Vice President of Strategic Initiatives (VP) has hired you as a risk management consultant.

Atria owns FirstMed, a Health Maintenance Organization (HMO) serving the state of Florida. In order to contain rising medical costs, the VP is contemplating outsourcing some of FirstMed’s surgical services from its affiliate Florida hospitals to Marazul Hospital Group (MHG), a hospital-physician group on the island of Montseguay.

You are provided the following information about Montseguay:

- A former British territory located in the Caribbean, a short distance from Miami
- Peacefully transitioned to independence from the United Kingdom in 2000
- English is the national language
- Experienced minimal impacts from hurricanes over the last 100 years
- Has one volcano that has been dormant for centuries

(a) (3 points) The VP is concerned that FirstMed’s operational risk will increase as a result of outsourcing to MHG.

(i) Explain two ways in which each of the following operational risks could increase for FirstMed if it outsources to MHG.

   I. People Risk
   II. Process Risk

(ii) Describe how each risk identified in (i) can be mitigated if Atria were to acquire MHG.

(b) (4 points) The VP has identified the following as emerging risks if FirstMed outsources to MHG:

- Technology / Artificial Intelligence
- Pandemic
- Environmental

(i) Explain why each of these risks may be considered an emerging risk.

(ii) Describe how each of these risks may be impacted by outsourcing.

(iii) Describe three best practices for future identification of emerging risks for FirstMed.
2. Continued

(c) (3 points) The VP thinks cyber risk would become one of FirstMed’s top risks should FirstMed proceed with the acquisition.

(i) Evaluate how an elevated cyber risk exposure may impact the following four risks for FirstMed. Justify your response.

I. Data Risk
II. Political Risk
III. Regulatory / Legal Risk
IV. Supplier / Third Party Risk

(ii) Recommend one action to mitigate each risk identified in part (i).

(d) (3 points) Because FirstMed has had no previous experience transacting in MontsCoin, the VP is concerned with the following additional risks:

- Exchange rate risk associated with transacting in MontsCoin
- Liquidity risk associated with transacting in MontsCoin
- Credit risk associated with outsourcing services to MHG

For each risk:

(i) Describe the risk as it relates to FirstMed.

(ii) Propose an appropriate risk management technique for FirstMed to implement.
3. (14 points) You are an actuary working in the Investment Department at JDY Life. JDY Life plans to offer a new indexed annuity product and is considering linking it to a composite index created by combining the ABC Fund and the XYZ Fund.

Your manager, Maggie, has asked for your assistance with understanding the correlation between the two funds for capital budgeting purposes and how it may change over time. Maggie has selected these two funds as she believes there may exist a natural hedge. She would ultimately like to model the joint distribution of the composite index using a copula and seeks an appropriate parameterization.

Maggie has provided you with the following information regarding the daily price change for each index over the past 30 days.

<table>
<thead>
<tr>
<th>Time (t)</th>
<th>ABC Fund (j_t)</th>
<th>XYZ Fund (k_t)</th>
<th>Rank of j_t</th>
<th>Rank of k_t</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30</td>
<td>-3.83%</td>
<td>-1.36%</td>
<td>28</td>
<td>23</td>
</tr>
<tr>
<td>-29</td>
<td>2.55%</td>
<td>0.14%</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>-28</td>
<td>2.11%</td>
<td>1.15%</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>-3</td>
<td>-0.68%</td>
<td>0.64%</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>-2</td>
<td>0.50%</td>
<td>0.02%</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>-1</td>
<td>-0.99%</td>
<td>-0.19%</td>
<td>23</td>
<td>18</td>
</tr>
</tbody>
</table>

Arithmetic Mean: -0.109% for ABC Fund, -0.155% for XYZ Fund
Variance: 0.034% for ABC Fund, 0.021% for XYZ Fund
Covariance: 18.45

(a) (3 points) In order to calibrate a copula for modeling the joint distribution of the two funds, you first must determine an appropriate correlation metric. You consider the following correlation coefficients:

- Pearson’s rho
- Spearman’s rho
- Kendall tau

Additional analysis shows that there are 253 concordant pairs of index returns in the dataset.

(i) Calculate each correlation metric based on the data provided. Show all work.

(ii) Describe the advantages and disadvantages of each metric that you should consider when selecting an appropriate correlation metric for parameterizing a copula.
(b) **(5 points)** The first step in forecasting correlation between the two funds is to forecast the volatility of the individual funds. In order to forecast the volatility of each fund’s value, you fit a GARCH(1,1) model, as shown below, to each series of fund returns:

\[ h_t = a_0 + a_1 r_{t-1}^2 + \beta h_{t-1} \]

The parameters for each model are provided in the following table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fund ABC</th>
<th>Fund XYZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a_0 )</td>
<td>0.0001</td>
<td>0.0002</td>
</tr>
<tr>
<td>( a_1 )</td>
<td>0.1610</td>
<td>0.2570</td>
</tr>
<tr>
<td>( \beta )</td>
<td>0.7770</td>
<td>0.5650</td>
</tr>
</tbody>
</table>

You are also given the initial observation of each of the funds:

<table>
<thead>
<tr>
<th>Time (t)</th>
<th>Fund ABC ( j_t )</th>
<th>Fund XYZ ( k_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>5.01%</td>
<td>4.89%</td>
</tr>
</tbody>
</table>

(i) Determine which fund has the higher expected variance. Show all work.

(ii) Assume that the \( t_0 \) conditional variances for each fund are equal to the empirical variances shown in the table on the previous page.

Calculate the conditional variances for the next two time steps, \( t=1 \) and \( t=2 \) for each fund using the GARCH(1,1) model. Show all work.

(iii) Maggie explains that there are simple modifications that can be made to the basic GARCH(1,1) model in order to more accurately reflect the behavior of typical financial time series.

Explain why the following modifications may be implemented for volatility forecasting:

- Using the absolute value of the innovation term
- Using a separate parameter for positive shocks and negative shocks

*Question 3 continued on the next page*
3. Continued

(c) (3 points) Maggie believes that the RiskMetrics approach is more appropriate than the GARCH model for forecasting the covariance between the two funds. She suggests using a risk decay factor of 0.95 and the empirical covariance as the t=0 conditional covariance.

The formula for forecasting the covariance using the RiskMetrics approach is given below.

\[ h_{t+1} = \lambda h_t + (1-\lambda)r_{1,t}r_{2,t} \]

(i) Identify two arguments in favor of using the RiskMetrics approach for forecasting covariance.

(ii) Calculate the forecasted t=1 Pearson correlation coefficient using the RiskMetrics approach and the results of part (b)(ii). Show all work.

(d) (3 points) Based on the results of your analysis, your team plans to implement the forecasting model to assess short-term capital adequacy for the annuity block.

(i) Explain how model risk could arise while calibrating and implementing the models described above.

(ii) Recommend three model validation best practices that could be incorporated to help manage and mitigate model risk. Justify your response.
Questions 4 and 5 pertain to the Case Study.
Each question should be answered independently.

4.  (11 points) Caerus Consulting has been hired by Big Ben to assess its economic capital framework and model. You have been asked to assist with this project.

Refer to section 0.7 of the Case Study.

(a)  (4 points) Prepare a SWOT analysis of Big Ben.

(b)  (4 points) Evaluate the following components of the economic capital model.

   I. The method used to quantify each risk.
   II. The capital allocation method.
   III. The model governance and validation.

(c)  (3 points) Big Ben asked Caerus to review the economic capital model’s risk aggregation technique to address the concern related to non-linear dependence and tail dependence among risk factors.

   (i) Evaluate the current risk aggregation method.

   (ii) Recommend a copula to aggregate the risks. Justify your answer.
Questions 4 and 5 pertain to the Case Study.
Each question should be answered independently.

5.  (14 points) You are an actuary in Caerus working with Big Ben. Refer to section 0.7 of the Case Study.

(a)  (3 points) Big Ben is evaluating its current Economic Capital (EC) model and has determined that the only shortcoming is the absence of liquidity risk in the model.

(i) Identify three additional shortcomings with the current EC process followed by Big Ben.

(ii) Recommend an improvement to address each of the shortcomings you have identified in (i).

(b)  (2 points) A recent FSA assigned to the task of evaluating Big Ben's liquidity risk has made the following report.

- The company is positioned well to handle all liquidity needs for the next six months
- Big Ben should obtain a letter of credit with another financial institution
- Big Ben should limit the types of assets to those in which the investing team has strong expertise. This would reduce the number of asset classes invested in by 50%

Critique each of these statements.

(c)  (4 points) A CERA in the ERM department states that a causal loop should be drawn to identify the impacts of the following liquidity-related events on the solvency of the bank.

- Increase in the cost of letters of credit
- Thinning of the real estate market
- Increase in mortgage prepayment rates
- Financial markets deepening
- Negative regulatory review
- Increase in interest rates
- Asset/liability mismatch increasing

Develop a causal loop for Big Ben failure indicating the type of relationship (“+” for a positive feedback / “-” for a negative feedback).
5. **Continued**

(d) **(3 points)** A new liquidity risk model for EC is created that calculates the required capital for this risk independently for each line of business. The quantile used for the VaR calculation is 99.5%.

The results of the model are shown in the table below.

<table>
<thead>
<tr>
<th>Economic Capital Required</th>
<th>Asset Management</th>
<th>Commercial Banking</th>
<th>Investment Banking</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquidity Risk</td>
<td>40</td>
<td>70</td>
<td>20</td>
<td>130</td>
</tr>
<tr>
<td>Revised Diversification Benefit</td>
<td>-110</td>
<td>-68</td>
<td>-46</td>
<td>-224</td>
</tr>
</tbody>
</table>

Assess if Big Ben still satisfies its capital adequacy objective globally and by line of business compared to its existing situation as shown in Exhibit C, table III of the Case Study. Show all work.

(e) **(2 points)** The following table shows the long-term expected risk-adjusted return and updated EC for each business unit after one year. The available capital for each business unit has not changed.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Asset Management</th>
<th>Commercial Banking</th>
<th>Investment Banking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk-Adjusted Return</td>
<td>70</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Total Required EC</td>
<td>530</td>
<td>300</td>
<td>220</td>
</tr>
</tbody>
</table>

(i) Calculate the RAROC and RARORAC for each line of business. Show all work.

(ii) Evaluate the performance of each of the business units relative to the other units based on the results of (i).

(iii) Evaluate the four future expansion plans for Big Ben outlined in the Case Study based on the results of (i).
6.  

(8 points) SLIC’s pension committee is interested in exploring different investment strategies and asks you to review the current pension plan. You have summarized SLIC’s current pension information for your analysis.

<table>
<thead>
<tr>
<th></th>
<th>Market Value (in millions)</th>
<th>Beta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond</td>
<td>$280</td>
<td>0.9</td>
</tr>
<tr>
<td>Equity</td>
<td>$420</td>
<td>1.5</td>
</tr>
<tr>
<td>Total Assets</td>
<td>$700</td>
<td>TBD</td>
</tr>
<tr>
<td>Liability</td>
<td>$900</td>
<td>1.1</td>
</tr>
</tbody>
</table>

(a)  

(2 points)

(i) Demonstrate that the current portfolio is not a minimum surplus variance portfolio.

(ii) Construct a portfolio by modifying the bond and equity mix which minimizes the surplus variance. Assume bond and equity betas remain the same.

A consulting firm presented to the pension committee an alternative approach to managing the portfolio using dual duration matching. The consulting firm also recommended adding COLA (cost of living adjustment) protection to the current plan. A consultant made a statement that SLIC should adopt a dual duration approach when adding a COLA to the plan.

(b)  

(1 point) Compare the dual duration approach and the single duration approach.

(c)  

(1 point) Evaluate the consultant’s suggestion that adopting a dual duration approach is appropriate when adding a COLA to the plan.

(d)  

(1.5 point) Recommend one duration matching approach for SLIC’s current pension plan. Justify your answer.
6. Continued

The consultant provided the following information on an illustrative 100% funded plan.

<table>
<thead>
<tr>
<th></th>
<th>Real Interest Rate Duration</th>
<th>Inflation Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal Bonds</strong></td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>TIPS</strong></td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td><strong>Equities</strong></td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td><strong>Liabilities</strong></td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

(e) (2.5 points) Assume a 10% equity allocation.

Construct the liability relative risk-free portfolio for the illustrative plan based on the dual duration matching approach. Show your work.
7. *(12 points)* The country of Atlantis has a thriving agricultural sector. However, it is often plagued by natural disasters. To fund and protect its growing agricultural sector over the next 5 years, Atlantis’s government works with the Big Ben Bank (“Big Ben”) to transfer the catastrophic risk to the financial markets.

Atlantis needs $10 million now to support this sector. Big Ben has agreed to issue the following securities to the markets, in order of seniority of payments:

- A $8 million notional, 5-year bond with annual coupon of 5% (Tranche T1)
- A $1.5 million notional, 5-year bond with annual coupon of 8% (Tranche T2)
- Big Ben will retain $0.5 million in equity (Tranche E).

The annualized yield from crops is assumed to be 12% of the principal remaining. The crop yields will be used to fund the coupons. Atlantis’s government will repay the outstanding principal at maturity.

Tranche E receives all residual payments after T1 and T2 are paid. Tranche E will lose capital before tranche T2, and T2 before T1.

The outstanding principal will automatically be reduced by $0.5 million per natural disaster occurrence.

Big Ben has assumed that for the next 5 years, the number of occurrences follows a binomial distribution, and the probability of an occurrence in each year is 5%. Big Ben has also assumed that there will be at most one occurrence per year.

(a) *(2 points)* Sketch a diagram showing all parties to the deal, as well as the cash flows among the different parties.

(b) *(1.5 points)* Describe the risk-reward profile for each tranche.

(c) *(1.5 points)* Critique Big Ben’s assumptions in modeling the occurrence of natural disasters.

For part (d) only, assume that there will be only one natural disaster and it occurs in year 2.

(d) *(3 points)* Calculate the total payments to Tranche E for each of the next 5 years. Show your work.
7. Continued

SLIC’s CIO, Max Hawke, is proposing a new investment strategy: adding structured securities to the General Account investment portfolio (see April 1, 2018 memo in Section 3.11 of the Case Study). Hawke is interested in purchasing Tranche T1 for SLIC’s General Account Corporate portfolio using new cash. The current market value of Tranche T1 is $8.5 million, with duration 5.76.

(e) \( (1.5 \text{ points}) \) Calculate the dollar duration of the Corporate portfolio of SLIC after adding Tranche T1. Show your work.

To remain compliant with SLIC’s market risk policy, Hawke needs to keep the duration of the Corporate portfolio unchanged upon adding Tranche T1. He wishes to use interest rate futures priced at $100,000 with duration 8.87 to rebalance the portfolio duration.

(f) \( (1 \text{ point}) \) Calculate the number of futures contracts needed to remain compliant with SLIC’s market risk policy. Show your work.

(g) \( (1.5 \text{ points}) \) Recommend whether SLIC should approve Hawke’s proposal to purchase Tranche T1. Justify your recommendation.

**END OF EXAMINATION**
USE THIS PAGE FOR YOUR SCRATCH WORK