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**SOCIETY OF ACTUARIES**  
**Enterprise Risk Management – Investment Extension**

# Exam ERM-INV

**Date:** Friday, May 6, 2016  
**Time:** 8:30 a.m. – 12:45 p.m.

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## INSTRUCTIONS TO CANDIDATES

### General Instructions

1. This examination has a total of 80 points.

This exam consists of 9 questions, numbered 1 through 9.

The points for each question are indicated at the beginning of the question. Questions 8 and 9 pertain to the extension readings and/or the Case Study, which 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.

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.**



**\*\*BEGINNING OF EXAMINATION\*\***

- 1.** (7 points) Arbutus Life sells 5-Year Guaranteed Investment Contracts (GICs), guaranteeing a fixed crediting rate that is determined at issue.

Its current product, Classic GIC, can be surrendered after two years at book value. Its reserves and capital are invested in investment grade bonds. Profitability is determined primarily from the spread between asset earnings and interest credited.

To combat the low interest rate environment, Arbutus has developed Enhanced GIC, which has similar profitability expectations to Classic GIC. It offers a higher crediting rate by investing a modest portion of the supporting assets into higher-yielding corporate bonds issued by Riley, Inc. In exchange for the higher crediting rate, Enhanced GIC cannot be surrendered.

Your role is to review the following Risk Based Capital (RBC) components for Arbutus:

- I. Asset Risk – Other
- II. Insurance Risk
- III. Interest Rate Risk
- IV. Business Risk

- (a) (1 point) Explain how each of the four RBC risk components pertains to the Classic GIC portfolio and its supporting assets.
- (b) (1.5 points) Explain how the RBC profile for Enhanced GIC differs from that of Classic GIC for each of the four RBC risk components.
- (c) (1 point) Explain why the introduction of Enhanced GIC may not generate a diversification benefit in total RBC for Arbutus.
- (d) (2 points) Arbutus calculates Economic Capital for the GIC block of business based on a prescribed Conditional Tail Expectation (CTE) measure of the modeled present value of profits over a large number of scenarios.

Explain how each of the four RBC risk components can be captured in such a model.

- (e) (1.5 points) Arbutus management is trying to decide whether to focus on RBC or Economic Capital for capital management purposes.

Recommend a course of action for Arbutus. Justify your response.

2. (10 points) Marpole Insurance Company (MIC) sells Private Mortgage Insurance (PMI) primarily in the state of California. U.S. lenders require that borrowers purchase PMI for new mortgage loans when the loan is more than 80% of the property value.

MIC's PMI product has the following characteristics:

- Level premiums are paid annually by the borrower based on the initial size of the loan. Premium rates are a function of the borrower's credit score.
- A claim equal to the outstanding loan balance is paid to the lender in the event that the borrower defaults.
- The insurance can be cancelled upon request of the borrower once the outstanding loan balance is less than 75% of the property value.

MIC invests the supporting assets primarily in short-term U.S. treasuries and high quality corporate bonds.

PMI is simple to administer and is sold by general agents who receive a modest commission based on premium.

MIC has repurposed its cash flow testing model to determine Economic Capital (EC). The model has been modified to run numerous economic scenarios as required for the EC calculation.

Attributes of the repurposed model include:

- Economic scenarios are generated from an internal economic scenario generator (ESG), which models equity values, credit spreads, U.S. treasuries, CPI inflation, U.S. home prices, and U.S. unemployment rates.
  - The claims assumption, based on previous company experience, is modeled as a function of the projected unemployment rate and loan-to-value (LTV) ratio.
  - The assumed time step in the model is one month and the projection period is the average loan maturity.
- (a) (1 point) Assess whether the PMI EC model is fit for its intended purpose.
- (b) (1 point) Describe aspects of model governance that MIC should have in place.
- (c) (3 points) Identify which specific aspects of the PMI EC model warrant most of the validation effort. Justify your response.

## 2. Continued

- (d) (3 points) Explain how you would apply each of the following model input validation tests to the key drivers of the PMI EC model:
- (i) Static Validation
  - (ii) Back-testing established distributions
  - (iii) Benchmarking
- (e) (2 points) Explain how you would apply each of the following model calculation validation tests to the key drivers of the PMI EC model:
- (i) Sensitivity testing parameters
  - (ii) Dynamic validation

3. (10 points) A trader holds 10,000 shares of XYZ. At time  $t = 0$ , she must calculate the 99% Value at Risk (VaR) of the potential 1-day loss in market value of the portfolio. She will use one of the two following models for the daily return. Daily return is defined as  $Y_t = \frac{S_t}{S_{t-1}} - 1$ , where  $S_t$  is the price of one share in XYZ at time  $t$  (measured in days).

Model 1: Daily returns are independent and identically distributed (i.i.d.), with

$$Y_t \sim N(0, \sigma^2), \quad \sigma = 0.016$$

Model 2: Daily returns follow a GARCH process, with

$$Y_t = \sqrt{h_t} \varepsilon_t$$

$$\varepsilon_t \text{ are i.i.d. with } \varepsilon_t \sim N(0, 1)$$

$$h_t = \alpha_0 + \alpha_1 Y_{t-1}^2 + \beta h_{t-1}$$

$$\alpha_0 = 7.7 \times 10^{-6}, \alpha_1 = 0.2, \beta = 0.77$$

You are also given the following initial conditions:

$$S_0 = 10.0, h_0 = 0.016^2, \text{ and } Y_0 = 0.05$$

- (a) (3 points)
- (i) Calculate the mean and standard deviation of  $Y_1$  under the GARCH model. Show your work.
  - (ii) Show that the unconditional standard deviation of daily returns under the GARCH model is 0.016 to the nearest 0.001.
  - (iii) Show that the daily returns  $Y_t$  and  $Y_{t+1}$  are uncorrelated under the GARCH model.
  - (iv) State with reasons whether the daily returns  $Y_t$  and  $Y_{t+1}$  are independent under the GARCH model.



### 3. Continued

(b) (3 points)

- (i) Calculate the 1-day 99% VaR at time zero using Model 1. Show your work.
- (ii) Show that the 10-day 99% VaR for Model 1 is approximately  $\sqrt{10} \times (1\text{-day } 99\% \text{ VaR})$ .

(c) (2.5 points)

- (i) Calculate the 1-day 99% VaR at time zero using Model 2. Show your work.
- (ii) Explain whether the 10-day 99% VaR will be greater than, less than or equal to  $\sqrt{10} \times (1\text{-day } 99\% \text{ VaR})$  for Model 2 based on the initial conditions provided in the stem above.

(d) (1.5 points) Explain why the GARCH model generates a higher 1-day 99% VaR than Model 1, even though the models have the same mean and long term variance.

- 4.** (8 points) A U.S. university maintains a large endowment fund (UEF). Investment income is used to support student scholarships and infrastructure expenditure, which require a regular, predictable income stream. The fund is managed by a Trustee Board appointed by the university.

The trustees have been working closely with a Local Investment Bank (LIB). Currently, the UEF has entered into the following contracts with LIB to manage or mitigate financial risk.

- I. An interest rate swap, under which the university pays the short term floating rate and receives a fixed rate of 4% at each year end. The nominal principal is \$100 million. The contract has three years remaining.
- II. Credit Default swaps with 2 years to maturity. The current Market Value (MV) is \$2 million.
- III. A European put option on the S&P 500 index with 3 months term to maturity. The option is far out-of-the-money. The current MV is \$5 million.
- IV. A currency swap, under which the UEF pays 5% per year in Euros (€) on notional principal of €100 million and receives 4% per year in US Dollars (\$) on notional principal of \$100 million. Payments are made at each year end. The contract has three years remaining.

- (a) (2 points) Each of the contracts with LIB was put in place to mitigate particular risks, based on the portfolio that the UEF has in place.

Explain a potential risk that the UEF could have been intending to mitigate for each of the four contracts.

- (b) (1 point) The UEF currently operates separate agreements for each of the four contracts. LIB is proposing that the separate agreements be replaced with a Master Agreement.

Explain the advantages and disadvantages, if any, to the UEF of this change.

## 4. Continued

(c) (3 points) The value of an interest rate swap to the party who receives an annual fixed rate of  $c\%$  and pays the floating rate, with remaining term  $n$  years, is the difference in value between an  $n$ -year,  $c\%$  annual coupon bond and an  $n$ -year floating rate note.

- (i) Explain why this description gives the market value of the swap.
- (ii) You are given that the current risk free rate of interest is 3% per year, compounded continuously.

Show that the current market value of the interest rate swap to the UEF is \$2.7 million to the nearest \$0.1 million.

- (iii) You are given that the Euro payments under the currency swap are valued at a flat rate of interest of 1% per year, compounded continuously. The U.S. dollar payments are valued at a flat rate of interest of 3% per year, compounded continuously. The current exchange rate is \$1.06 to €1.00.

Show that the current market value of the currency swap is \$-2.7 million, to the nearest \$0.1 million.

(d) (2 points) The UEF is concerned about counterparty risk.

- (i) Define “current exposure” and “expected potential exposure” in the context of the UEF’s credit risk exposure to LIB.
- (ii) Calculate the current exposure of the UEF to LIB assuming full netting applies. Show your work.
- (iii) Calculate the current exposure of the UEF to LIB assuming no netting. Show your work.
- (iv) Explain the underlying premise that justifies using a netting approach.

- 5.** (9 points) You work as a risk analyst for an insurance company offering two products: Level Premium Whole Life Insurance and Single Premium Immediate Annuity (SPIA).

Assets are invested 60% in a combination of corporate and government bonds and 40% in equities.

Liabilities are valued on a market consistent basis. The liabilities are split 55% for the Whole Life business and 45% for the SPIA business.

- (a) (2 points) Describe the company's exposure to the following risks:
- (i) Interest rate risk
  - (ii) Equity asset value risk
  - (iii) Catastrophic mortality risk
  - (iv) Trend mortality risk (also known as longevity risk)
- (b) (2.5 points)
- (i) A colleague suggests combining single factor sensitivity test results for each of the items in (a) to assess economic capital for the firm.  
  
Critique this suggestion.
  - (ii) Explain why the company's liability valuation model may not be appropriate to use to evaluate the economic capital.

The firm decides to assess economic capital based on a 1-year stress test. You plan to stress test the asset values using a copula to generate a 1-in-200 year stress scenario.

The current value of the bond portfolio is 600. The bond portfolio value in one year is assumed to follow a normal distribution with parameters  $\mu_b = 630$  and  $\sigma_b = 60$ .

The current value of the equity portfolio is 400. The equity portfolio value in one year is assumed to follow a lognormal distribution with parameters  $\mu_e = 6.0$  and  $\sigma_e = 0.35$ .

## 5. Continued

You assume that the dependency between the bond and equity portfolio values is modeled with a  $t$  copula with  $\rho = 0.8$  and with 4 degrees of freedom. You are given the following table of values for the  $t$  copula:

		$v$					
		<b>0.005</b>	<b>0.006</b>	<b>0.007</b>	<b>0.008</b>	<b>0.009</b>	<b>0.010</b>
$u$	<b>0.005</b>	0.0026	0.0028	0.0030	0.0031	0.0033	0.0034
	<b>0.006</b>	0.0028	0.0030	0.0033	0.0035	0.0037	0.0039
	<b>0.007</b>	0.0030	0.0033	0.0036	0.0039	0.0040	0.0042
	<b>0.008</b>	0.0031	0.0035	0.0039	0.0041	0.0044	0.0046
	<b>0.009</b>	0.0033	0.0037	0.0040	0.0044	0.0050	0.0052
	<b>0.010</b>	0.0034	0.0039	0.0042	0.0046	0.0052	0.0054
		$t$ copula, $C(u,v)$					

- (c) (1 point) Describe the  $t$  copula and explain its main features.
- (d) (2.5 points) You generate a 1-in-200 year stress event assuming each portfolio lies at its  $q$ -quantile for some  $q$  (the same  $q$  is used for both portfolios).
- (i) Determine the quantile  $q$  which exactly satisfies this constraint. Show your work.
  - (ii) Calculate stressed values of the bond and equity portfolios in one year using  $q$  from (i). Show your work.
- (e) (1 point) Your colleague suggests using a Gaussian copula with  $\rho = 0.8$ .

Explain whether the resulting stress test would be more severe or less severe than the results using the  $t$ -copula above.

**6.** (10 points) Grandview Insurance is a property and casualty insurer operating in a country prone to earthquakes. A recent series of earthquakes has strained its surplus level due to major losses from the commercial line. The commercial line insures losses from property damage and business interruption (“PDBI”). The CRO is considering PDBI reinsurance coverage to transfer some of the risk arising from earthquake claims and associated earnings volatility.

(a) (2 points) Describe the following types of reinsurance and assess the suitability of each for PDBI risks.

- (i) Quota Share
- (ii) Stop Loss

The following is an excerpt from an ordered sample of 200 simulated annual losses for Grandview’s PDBI line, in millions.

$i$	$L_i$
$\vdots$	$\vdots$
195	43.8
196	47.5
197	50.2
198	57.5
199	65.6
200	90.0

Grandview is considering the following three options:

- I. No reinsurance coverage
- II. A quota share reinsurance arrangement under which Grandview cedes 35% of the risk
- III. A stop loss reinsurance arrangement with a 12 million priority and 40 million capacity

(b) (2.5 points) Calculate the 98% CTE of the net losses after reinsurance recoveries for each reinsurance option. Show your work.

**6. Continued**

You are given the following formula for the standard error of the CTE, where  $\widehat{Q}_\alpha$  is the estimate of the  $\alpha$ -quantile of the loss, using the simulations, and  $\widehat{CTE}$  is the estimated  $\alpha$ -CTE of the annual loss in (b) above. Var denotes the variance.

$$\left( \frac{\text{Var} \left[ L | L > \widehat{Q}_\alpha \right] + \alpha \left( \widehat{CTE} - \widehat{Q}_\alpha \right)^2}{N(1-\alpha)} \right)^{0.5}$$

(c) (1.5 points)

- (i) Estimate the standard error of the CTE estimator in (b) for the Quota Share Reinsurance.
- (ii) Estimate the standard error of the CTE estimator in (b) for the Stop Loss Reinsurance.

Show your work.

(d) (2 points) You are given the following:

Reinsurance	Premium	Expected Recoveries
Quota Share	2.0 million	1.5 million
Stop Loss	2.5 million	1.4 million

The CFO reviews the risk measure calculations and premiums, and sends the following email:

“The expected payouts from the two reinsurance contracts are close. The Quota Share is cheaper, so we don’t need any further analysis. We should go with the Quota Share.”

- (i) Explain why the Quota Share contract is cheaper than the Stop Loss, per unit of expected reinsurance claim.
  - (ii) Critique the CFO’s statement.
- (e) (2 points)
- (i) Explain briefly how Grandview could use securitization instead of reinsurance for its earthquake risk.
  - (ii) State one advantage and one disadvantage of using securitization instead of reinsurance for Grandview’s earthquake risk.

7. (6 points) Oakridge is a multi-line insurance company with the following product lines:

- Term Life
- Universal Life
- Long-Term Disability
- Auto Insurance

Oakridge has just developed the following guiding principle for its Risk Appetite Statement (RAS).

*All material risks shall be actively managed and controlled to withstand a 1-in-100 year event.*

You have been asked to reevaluate the company's liquidity policy in view of the new RAS guiding principle.

The current liquidity policy states:

- Cash and equivalents shall be no less than the maximum weekly cash outflows during the past 3 months
- Liquid assets cannot be less than 50 percent of the total assets

(a) (1 point) Explain three high-level weaknesses of the current liquidity policy.

You have been asked to update the liquidity risk policy. You start by examining the liability liquidity risk profile.

You have been given the following product information:

- Term Life: 30-year fixed premium term life with no cash surrender value
- Universal Life: Flexible premium UL with minimum guaranteed interest; cash surrender benefit is subject to 7-year surrender charge schedule
- Long-Term Disability: Benefits payable from date of disability to age 65
- Auto Insurance: Yearly-renewable with average claim settlement period of 3 years.



## 7. Continued

You focus on the following key sources of liquidity risk:

- Credit rating downgrade impact
- Normal operational cash flow volatility
- Catastrophe risk
- Interest rate risk
- Adverse mortality, morbidity and claim experience

(b) (2.5 points)

- (i) Describe how each of the five sources impacts liquidity risk.
- (ii) Determine whether each of the sources of risk is high, medium, or low impact for each of the above four product lines. Justify your responses.

The Risk Management Department has proposed a revised liquidity policy, based on industry best practices for liquidity risk management, as follows:

Available Liquidity must be no less than 110% of the Required Liquidity, where

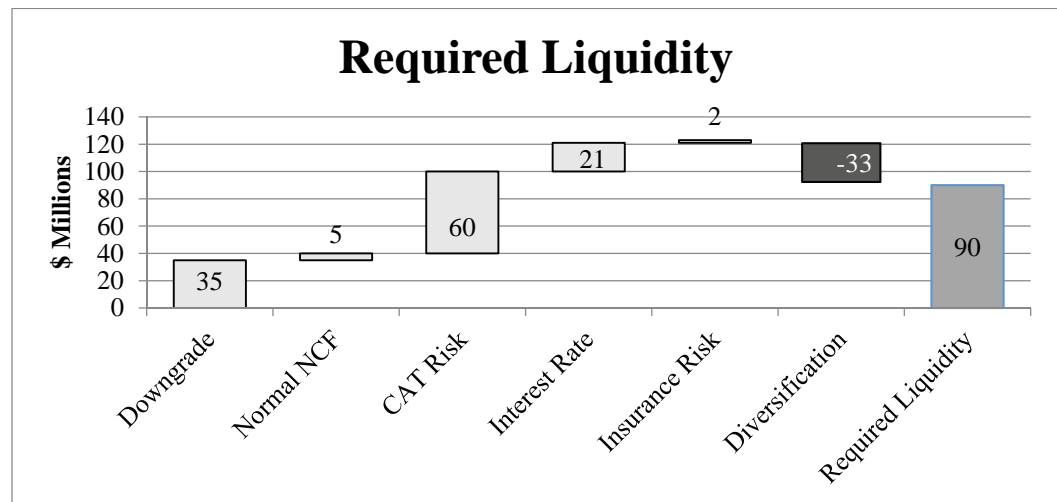
- Available Liquidity is provided by the Investment Management Department per industry common practice.
- Required Liquidity is the projected cash outflows for 3 continuous months in a 1-in-100 year event

*Question 7 continued on next page.*

## 7. Continued

You are given:

- Total assets = \$189 million
- Liquid assets = \$96 million



(c) (1 point)

- Describe Oakridge's liquidity position relative to the current policy.
- Describe Oakridge's liquidity position relative to the proposed policy.

(d) (1.5 points) Oakridge decides to adopt the proposed liquidity policy.

Explain three actions that Oakridge could take to improve its liquidity risk position.

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*Questions 8-9 pertain to the Case Study and/or extension readings.  
Each question should be answered independently*

**8.** (11 points) You are an investment actuary at SLIC. The Pension Committee of SLIC’s Defined Benefit Pension Plan (the “Plan”) has asked you to identify and explain investment strategies that could be used to manage equity tail risk.

(a) (1 point)

- (i) Explain the term “volatility clustering” to the Committee.
- (ii) Describe why equity volatility clustering can be used to reduce tail risk.

You further explain to the committee that investors who use volatility for tail-risk hedging can purchase volatility exposure either over-the-counter (OTC) or on an exchange.

(b) (2 points)

- (i) Identify and describe one OTC contract and one exchange-traded instrument that could be used to hedge equity volatility exposure.
- (ii) Describe the advantages and disadvantages of each.

You demonstrate to the Committee how the one-month (25 business days) volatility of the S&P 500 Index can be predicted using an exponentially weighted moving average (EWMA) variance estimator model as follows:

$$h'_t = \lambda h'_{t-1} + (1 - \lambda) s_{t-1}^2$$

$$s_{t-1}^2 = \sum_{k=1}^{25} r_{t-k}^2$$

You have determined the following current values:

$$s_{t-2}^2 = \sum_{k=1}^{25} r_{t-1-k}^2 = 0.1791\%$$

$$s_{t-1}^2 = \sum_{k=1}^{25} r_{t-k}^2 = 0.1960\%$$

$$h'_{t-2} = 0.1895\%$$

$$h'_{t-1} = 0.1892\%$$

## 8. Continued

- (c) (2 points) Forecast the one-month volatility of the S & P 500 index. Show your work.

You suggest to the committee that equity variance forecasting can be used to implement a “Constant Volatility” investment strategy to manage equity tail risk exposures.

- (d) (1 point) With respect to a “Constant Volatility” strategy:
- (i) Describe the principle underlying the constant volatility strategy.
  - (ii) Explain the rationale for maintaining a constant volatility.

The Plan has \$250 million invested in a U.S. equity fund that is benchmarked against the S&P 500. The fund has a market beta of 1.1. You wish to demonstrate how a constant volatility overlay strategy could be implemented with respect to this fund.

Assume the following:

- The Plan wants to target the monthly equity fund volatility to 4.3300%, the historical monthly volatility of the S&P 500.
  - The current level of the S&P 500 Index is 2,000.
  - S&P 500 Index one-month futures contracts have a size of \$500,000.
  - You predict a 4.8114% volatility level of the S&P 500 Index over the next month.
- (e) (4 points)
- (i) Design the constant volatility overlay required to achieve the Plan’s target volatility using long/short investments in cash.
  - (ii) Design the constant volatility overlay required to achieve the Plan’s target volatility using one-month S&P Futures contracts.

Show your work.

*Question 8 continued on next page.*

## **8. Continued**

- (f) *(1 point)* The Plan's Pension Consultant has recently recommended that the Committee consider a new allocation to a U.S. equity portfolio manager who runs a "Constant Volatility" fund. You feel that the constant volatility overlay strategy using futures is a better choice for the plan.

Identify two key advantages of the constant volatility overlay strategy compared with a new investment in the Constant Volatility fund.

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**Questions 8-9 pertain to the Case Study and/or extension readings.  
Each question should be answered independently**

**9.** (9 points) You are an Investment Actuary at SLIC. Janis Baer, the VP of Human Resources, has asked for your assistance with respect to the investment strategy of SLIC’s DB Pension Plan.

During its annual review, the Plan Actuary asked the Pension Committee to consider changes to its efficient frontier approach in setting the Plan’s normal asset allocation. Currently, a traditional mean-variance optimization (MVO) framework with a 95% VaR metric is used to determine the optimal asset allocation.

Specifically, the Plan Actuary has suggested that:

- I. A mean conditional value at risk (M-CVaR) optimization be used instead of MVO, and
- II. Simulated non-normal returns be used in the optimization.

Janis has asked you to prepare a report for the Pension Committee to assist them in understanding and responding to the Plan Actuary’s suggestions.

To develop your report, you perform an efficient frontier study considering three hypothetical asset classes with return characteristics as follows:

	Expected Return	Volatility	Correlation		
			Asset A	Asset B	Asset C
Asset A	5%	7.5%	1	0.3	0.3
Asset B	9%	14.0%	0.3	1	0.8
Asset C	12%	18.0%	0.3	0.8	1

You test four scenarios with respect to the assets’ assumed statistical properties, where kurtosis is defined as the fourth central moment of the distribution:

		Asset A	Asset B	Asset C
Scenario 1	Skewness	0	0	0
	Kurtosis	3	3	3
Scenario 2	Skewness	0	0	0
	Kurtosis	3.5	3.5	6
Scenario 3	Skewness	0	0	-0.5
	Kurtosis	6	6	6
Scenario 4	Skewness	0	-0.1	-0.5
	Kurtosis	3.5	3.5	6



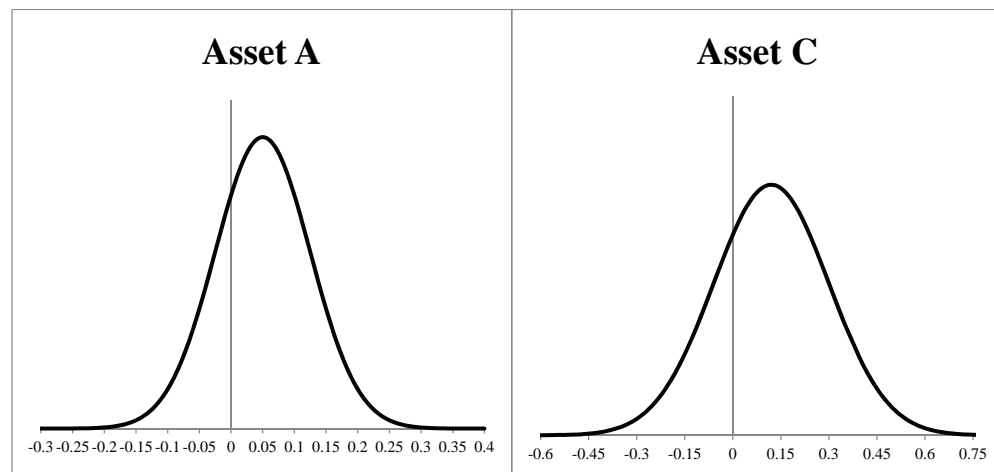
## 9. Continued

For Scenario 1, consistent with SLIC's current approach, you use a traditional quadratic optimization routine to determine MVO and M-CVaR optimal portfolios.

For Scenarios 2-4, you determine MVO and M-CVaR optimal portfolios based on simulated returns from stable distributions that reflect the scenario assets' indicated 3rd and 4th moments.

- (a) (2 points) Explain the objective of each of your four scenario tests.

You plot the Scenario 1 distributions for each of Asset A and Asset C returns as follows:

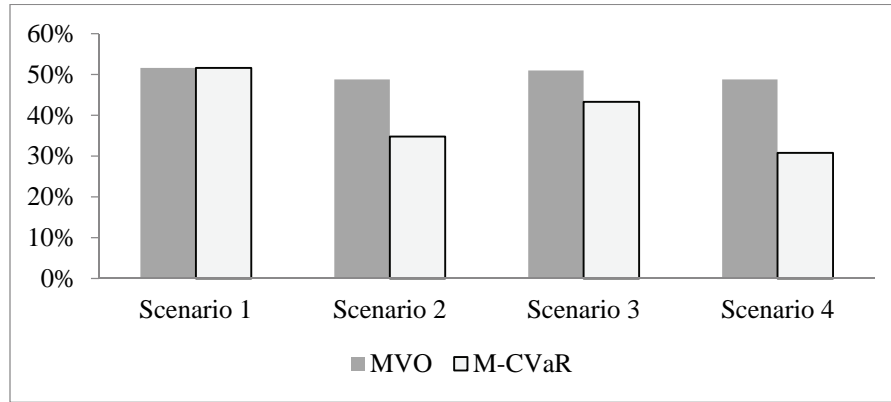


- (b) (1 point) Sketch and describe the change in the distribution of returns for Scenario 4 relative to your Scenario 1 plots with respect to:
- Asset A
  - Asset C

*Question 9 continued on next page.*

## 9. Continued

For a 9% target portfolio return, the two optimization frameworks produce the following Asset C allocations under each of the four scenarios:



- (c) (2 points) Provide four key observations about the impact of skewness and kurtosis on asset allocation differences that result from MVO and M-CVaR optimization using your Scenario results above.
- (d) (1.5 points) Detailed results for your Scenario 2 test for a 9% target portfolio return were as follows:

Scenario 2	Asset A	Asset B	Asset C
MVO	36.7%	14.5%	48.8%
M-CVaR	26.0%	39.2%	34.8%

Scenario 2	Std. Dev.	Skewness	Kurtosis	Risk Exposure	
				VaR	CVaR
MVO	11.5%	0	4.6	10.2%	20.1%
M-CVaR	11.9%	0	3.9	11.7%	19.0%

Compare and explain the Scenario 2 risk exposure results for each of the MVO and M-CVaR portfolio optimization frameworks.

- (e) (2.5 points) Your report to the Pension Committee recommends adoption of both of the Plan Actuary's suggestions.

Draft the rationale for your recommendation, making reference to your efficient frontier study results.

**\*\*END OF EXAMINATION\*\***

**USE THIS PAGE FOR YOUR SCRATCH WORK**

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