

# Exam ERM-INV

**Date:** Thursday, May 5, 2022

## INSTRUCTIONS TO CANDIDATES

### General Instructions

1. This examination has 8 questions numbered 1 through 8 with a total of 80 points.

The points for each question are indicated at the beginning of the question. Questions 3 and 6 pertain to the Case Study and questions 7 and 8 pertain to the Case Study and/or extension readings.

2. 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 provided in this document.

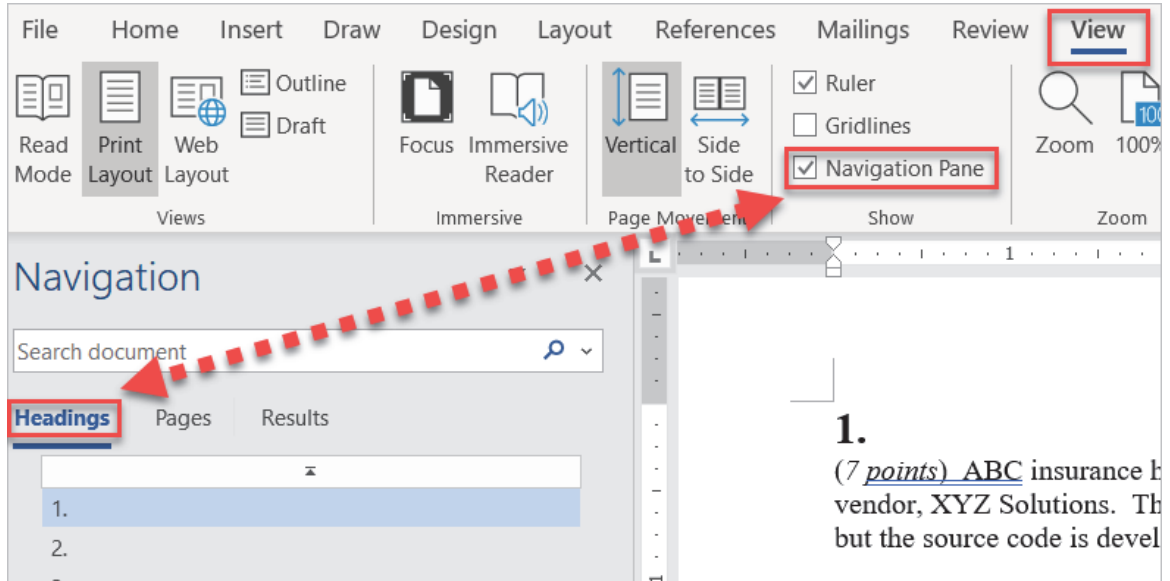
### Written-Answer Instructions

1. Each question part or subpart should be answered either in the Word document or the Excel file as directed. Graders will only look at work in the indicated file.
  - a) In the Word document, answers should be entered in the box marked ANSWER. The box will expand as lines of text are added. There is no need to use special characters or subscripts (though they may be used). For example,  $\beta_1$  can be typed as beta\_1 (and ^ used to indicate a superscript).
  - b) In the Excel document formulas should be entered. Performing calculations on scratch paper or with a calculator and then entering the answer in the cell will not earn full credit. Formatting of cells or rounding is not required for credit.
  - c) For each question part requiring an answer in Excel, (1) clearly identify the inputs to the calculations, (2) show the necessary interim calculations, adding rows and / or columns, if necessary, and (3) enter the final answer in some or all of the cells highlighted in yellow, as applicable in each circumstance. These cells should contain formulas with links to other calculations in the worksheet. Minimize the use of hard-coded figures and maximize the number of interim steps in the calculations that would demonstrate your line of thinking.
2. The answer should be confined to the question as set.
3. Prior to uploading your Word and Excel files, each file should be saved and renamed with your five-digit candidate number in the filename.
4. The Word and Excel files that contain your answers must be uploaded before the five-minute upload period expires.

## Navigation Instructions

Open the Navigation Pane to jump to questions.

Press Ctrl+F, or click View > Navigation Pane:



## **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.

(9 points) Acme, a stock company, sells life insurance, annuities, and pet insurance. You have been tasked with building an Economic Capital (EC) model for Acme. Acme's performance on the life business has shown poor results due to excess COVID-19 deaths.

Acme has three Business Units (BU) A, L and P. Acme's management will use the EC by BU to determine risk-adjusted returns for the managers of the BUs. Risk Capital (RC) amounts for each BU as standalone entities are as follows:

BU	Line of Business	RC
A	Annuities	100
L	Life	50
P	Pet	25

(a) (2 points)

(i) Identify and describe four of Acme's *key* stakeholders.

ANSWER:

(ii) Outline the RC considerations of each key stakeholder, reflecting Acme's recent experience.

ANSWER:

## 1. Continued

(b) (1.5 points) Acme's management is considering a restructure, whereby some BUs would be divided and a new BU added. The proposed structure is described as follows:

- A is divided into two, unequal parts
- L is divided into two, identical parts
- P is unchanged
- N is the new business unit, which is considered risk-free.

The proposed new capital allocation is as follows:

<b>BU</b>	<b>RC</b>
A <sub>1</sub>	95
A <sub>2</sub>	4
L <sub>1</sub>	30
L <sub>2</sub>	20
P	15
N	5

Assess whether the new allocation satisfies the requirements of a Coherent Capital Allocation methodology by comparing the proposed RC allocation to the existing allocation.

ANSWER:

## 1. Continued

- (c) (5.5 points) Acme's management decided not to proceed with the restructure but wants to free up as much capital as possible. Management believes it can reduce the overall EC amount by taking into account the correlations between BUs.

You are given the following correlation matrix:

	<b>A</b>	<b>L</b>	<b>P</b>
<b>A</b>	1.0	0.7	0.3
<b>L</b>	0.7	1.0	0.4
<b>P</b>	0.3	0.4	1.0

- (i) Demonstrate that the amount by which total capital can be reduced with diversification is 24.58. Assume that the risks are normally distributed.

*The response for this part is to be provided in the Excel spreadsheet.*

- (ii) Calculate the amount of RC for each BU using the Pro Rata (linear) approach. Show all work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (iii) Calculate the amount of RC for each BU using the Discrete Marginal Contribution approach. Show all work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (iv) Recommend either the Pro Rata or the Discrete Marginal Contribution method of allocation for Acme. Justify your answer.

ANSWER:

## 2.

(11 points) Addison Carter, the CFO of a small dental and vision insurer, has recently been given the additional title of CRO. She has approached you for consulting services. Her company uses an internal model to determine VaR for its investment portfolio of \$30 million in assets. The model was built by one of her two risk analysts and has been in use for one year.

Recently, the Board of Directors has expressed concerns that monthly reported VaR levels fluctuate significantly even though the portfolio change has been immaterial. There have also been two months in the past year where reporting was unavailable due to output errors from the model. The Board is losing confidence in the model's ability to appropriately assess investment risk and has requested an external review of the model.

(a) (3.5 points) The first objective of the external review is to assess the VaR model's design. Addison describes the methodology, data and assumptions as follows:

- The model uses parameters based on one year of historical market data as inputs to calculate VaR
- The calculation employs a Monte Carlo simulation and assumes that changes in risk factors follow a well-defined distribution, e.g., normal distribution or t-distribution
- To determine aggregated VaR, the model assumes correlations between the risk factors and a t-copula to incorporate increased correlation in the tail of the combined distribution
- The correlation assumptions are based on recent data and they have been backtested.

Critique the model design.

ANSWER:
---------

## 2. Continued

- (b) (3.5 points) After your review of the model design, Addison indicates she would like to address the Board’s concerns, beginning with the monthly VaR fluctuations. Monthly data updates involve appending new data from a public online source (“data pull”) to the existing data set.

The following changes have been made to the monthly update process since model inception:

- The implementation of a simple process to identify and remove duplicated data
- The automation of the monthly data pull
- The recent requirement of an approval from IT once the data has been appended.

You review the data from the online source and find that it contains duplicates at times and that the format is not standardized. For example, it may be reported in thousands or millions depending on the size of recent market movements. You also learn that the internal approval process does not include a review of the data.

You next review the internal data to address incidents of VaR errors. In your review, you note the following:

- Some of the fields in the data are empty
- Expected returns for some of the investments in their system are negative
- The model is meant to aggregate the risk for four different risk factors in the investment portfolio, but the risk type field for each entry is restricted to only three choices.

The company has an internal requirement to follow Moody’s Data Quality practices.

- (i) Describe the most critical step in the Moody’s recommended seven-step quality process that is not being followed. Justify your response.

ANSWER:

- (ii) Describe the two most critical data quality rules applicable to this data. Justify your response.

ANSWER:



## 2. Continued

- (c) (4 points) After addressing issues found in your review, the internal VaR model appears to be capturing aggregate tail risk appropriately. The Board wants to understand the specific conditions that could result in tail losses and whether there would be any associated long-term impacts to their business. Addison is considering complementing their current VaR analysis with scenario and sensitivity analysis.

The company's investment portfolio is 65% investment grade bonds, 30% equities and 5% cash equivalents.

Addison has decided to begin with a sensitivity analysis where there is a 5% decline in the equity markets. She would use the resulting impact to the investment portfolio to enhance the reporting to the Board.

- (i) Critique Addison's decision.

ANSWER:

You tell Addison that other scenario types should also be considered. Addison returns with the following scenarios:

- Single Factor Scenario – an unexpected spike in claims that requires the liquidation of 10% of the investment portfolio at current market prices
- Multi-Factor Stress Scenario – a 1-year recession that depresses the market value of equities in the portfolio, results in defaults in their bond portfolio and drives inflation resulting in increased claim costs and a slight dip in business volume late in the year
- Multi-Factor Multi-Period Stress Scenario – a severe, 2-year market downturn that increases the severity of the Multi-Factor Stress Scenario. Additionally, the scenario reflects a significant reduction to investment income and business volumes in year 2.

- (ii) Evaluate each scenario type given the Board's needs and Addison's available resources.

ANSWER:

## 2. Continued

- (iii) Recommend the most appropriate scenario type based on your analysis in part (ii). Justify your response.

ANSWER:

**Questions 3 and 6 pertain to the Case Study.  
Each question should be answered independently**

**3.**

(12 points) The Massachusetts regulator has recently reviewed Lyon's ORSA and provided feedback. The regulatory response included several critical comments of items that need to be addressed. As an actuary on the newly formed Corporate Risk Committee, you have been asked to provide responses and recommend improvements to Lyon's ERM framework and future ORSA reporting.

Refer to sections 2.11 and 2.12 of the Case Study.

- (a) (2 points) The following feedback was provided by the regulator:

“A key weakness of Lyon's approach to the group capital assessment of the enterprise in the ORSA is the lack of group-level analysis.”

Explain the issue raised by the regulator using two relevant examples from the Case Study.

ANSWER:

- (b) (2 points) Another key issue raised was that Lyon's Corporate capital quantification for credit risk is not modeled, even though credit risk is a key risk for the enterprise.

A consultant was hired to develop loss scenarios on the Corporate asset portfolio. He produced the following results.

Percentile	Loss (in 000s) at end of year
75%	\$5,450
90%	\$9,681
95%	\$14,368
98%	\$17,725

Evaluate the reasonableness of Lyon's Corporate Economic Capital value for Credit Risk given these scenario results.

ANSWER:

### 3. Continued

(c) (2 points) Senior management has requested that the Corporate Risk Committee develop improvements to the ORSA for next year's submission.

(i) Explain how stress and scenario testing can improve Lyon's ERM framework and ORSA reporting.

ANSWER:

(ii) Describe two items that regulators will consider when evaluating stress testing in the ORSA report.

ANSWER:

(d) (6 points) Senior management has requested several enhancements to the group capital assessment and scenario/stress testing. The first recommendation is to develop an Operational Risk provision for the enterprise.

(i) Describe two quantitative approaches to modeling Operational Risk that would be appropriate for Lyon.

ANSWER:

(ii) Explain the considerations of the following as they relate to data used in modeling Operational Risk:

- Internal vs External data
- Hard vs Soft data.

ANSWER:

### 3. Continued

For calculating Operational Risk capital, a colleague suggests using a Generalized Pareto Distribution with a threshold at \$1 million, the calibrated shape parameter at 0.80 and the calibrated scale parameter at 0.5.

$$Q_a = d + \frac{b}{k} \left( \left( \frac{S_x(d)}{1-a} \right)^k - 1 \right)$$

There are a total of 500 loss values collected across the businesses. You are provided the following table showing the top 30 largest losses, in millions of dollars.

12.33	8.71	6.74	4.41	4.20
3.31	2.97	2.65	2.58	2.40
2.29	2.21	2.12	1.89	1.76
1.35	1.34	1.28	1.27	1.25
1.15	1.13	1.10	1.07	1.05
0.99	0.97	0.96	0.92	0.91

- (iii) Calculate the 99<sup>th</sup> percentile of operational losses using the GPD. Show all work.

ANSWER:

- (iv) Evaluate the result from (iii) and discuss how it relates to the economic capital held by Lyon. Justify your answer using information from the Case Study.

ANSWER:

#### 4.

(12 points) ABC is a health insurer that writes comprehensive medical, dental, and vision coverages. Due to the COVID-19 pandemic, ABC has established an asset liquidity risk limit system as one of its risk management mechanisms. Two of the limits are shown below, both assessed over a one-year time horizon.

Application	Asset Liquidity Risk Limit(s)	Risk Owner	Mitigation Requirement Upon Breach
Individual assets	LVAR/VAR – 1 < 35% for each individual asset at a confidence level of 95%	CIO	CIO analysis and risk report to Risk Committee; no explicit action required
Asset portfolio	LVAR/VAR – 1 < 25% for the portfolio of assets at a confidence level of 95%	CIO	Breach required to be corrected within 30 days of triggering event

Recent risk monitoring activity has indicated a breach in the portfolio-level asset liquidity risk limit. To correct the breach, the Chief Investment Officer (CIO) intends to sell one of the four following assets. Assume the following:

- All proceeds will be held as cash.
- Bid/ask spreads will not change upon liquidation.
- All the assets are unaffiliated.

Asset	Market Value	Statutory Book Value	Bid/Ask Spread	Volatility ( $\sigma$ )	Post-tax RBC Factor
BBB Corp Bond	245.0	250.0	0.30	0.30	0.010
BB Corp Bond	242.0	252.0	0.47	0.38	0.020
B Corp Bond	244.0	248.0	0.70	0.65	0.045
Equity	240.0	244.0	1.80	2.00	0.150

#### 4. Continued

- (a) (4 points) In considering which asset to sell, the CIO asks you if any of the four assets have breached the individual asset liquidity limit. Assume a normal distribution and critical value of 1.645.
- (i) Determine which, if any, of the individual assets have breached the asset liquidity limit. Show all work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (ii) Recommend which asset to sell based on the results in (i). Justify your response.

ANSWER:

- (b) (5 points) The CIO communicates internally the intent to sell the asset based on your recommendation. ABC's CFO points out that the impact on the company's RBC ratio may vary depending on which asset is sold, and this should be considered when determining which asset to sell.

ABC uses the NAIC Health RBC formula when calculating the RBC ratio. The following table shows book values and average post-tax RBC factors by risk category used by ABC to calculate its RBC ratio.

RBC Category	Book Value	Average post-tax RBC Factor
H0	1,299	0.030
H1	23,612	0.022
H2	32,000	0.044
H3	12,478	0.032
H4	2,220	0.050

Total Adjusted Capital (TAC) = 5,527

- (i) Describe what RBC is intended to measure.

ANSWER:

#### 4. Continued

- (ii) Assume that cash held on the balance sheet has a 0% RBC factor.

Analyze the impact on the company's RBC ratio of selling each individual asset from part (a). Show all work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (iii) Discuss whether your analysis performed in part (ii) has changed your prior recommendation to the CIO on which asset to sell. Justify your response.

ANSWER:

- (c) (3 points) The CIO wants to review the company's liquidity contingency plan.

- (i) Outline the main components of a well-designed liquidity contingency plan as part of a broader liquidity risk framework.

ANSWER:

- (ii) Explain how a catastrophic event could impact the liquidity needs of ABC.

ANSWER:

- (iii) Identify three factors, other than a catastrophic event, that could impact the level of ABC's available liquidity.

ANSWER:



## 5.

(10 points) Magenta Rock sells life insurance and fixed annuity products.

You are a consulting actuary hired by Magenta Rock to review its asset-liability management (ALM) practices. The company recently established an Asset-Liability Committee (ALCO) to oversee asset-liability duration matching.

You are given the following information about the company's products:

- Investment returns on the life insurance business are lower than assumed in pricing.
- The fixed annuities have a guaranteed minimum interest rate, and contract-holders can withdraw their funds on demand without penalty. Interest margins are currently below those assumed in pricing.
- The effective duration of the liabilities is much longer than the effective duration of the assets for both products.

During your initial meeting with the company, Magenta Rock's CFO, Juan, states: "I believe we spend too much time worrying about the duration gap between our assets and liabilities. Given that Magenta Rock reports its financials on a book value basis, the primary focus of the ALCO should be to minimize absolute risk from asset volatility and minimize accounting volatility."

- (a) (2 points) Evaluate the assertions made by Juan.

ANSWER:

- (b) (3 points) At a follow-up meeting, the ALCO expresses concerns regarding the current low interest rate environment and the volatility of the economic surplus. The ALCO suggests immunizing Magenta Rock's portfolio.

- (i) Describe two ways in which Magenta Rock would still be exposed to interest rate risk even if the portfolio is immunized using effective duration.

ANSWER:

- (ii) Recommend a strategic asset allocation framework that would help increase Magenta Rock's portfolio yield while still addressing its concerns of surplus volatility. Justify your response.

ANSWER:

## 5. Continued

- (c) (2 points) To further test the impact of the current interest rate environment, an ALCO member suggests that the following scenario test should be conducted:

A 50 basis point parallel drop in the risk-free rates for one year followed by an additional 10 basis point drop for each of the next four years.

- (i) Assess how Magenta Rock's ALM profile would be impacted under the stress test circumstances.

ANSWER:

- (ii) Recommend one additional method Magenta Rock could use to measure interest rate risk to complement the scenario testing. Justify your recommendation.

ANSWER:

- (d) (1 point) During your review of ALCO's practices, you notice that credit risk was overlooked when analyzing future asset cash flows.

Describe how Magenta Rock could incorporate its credit risk exposure into the projected asset cash flows.

ANSWER:

- (e) (2 points) You suggest to the ALCO that the volatility of the liability cash flows could be minimized using risk transfer methods or derivatives.

Explain how each of the following methods could be used to minimize the volatility of Magenta Rock's liability cash flows:

- Reinsurance
- Interest rate swap

ANSWER:

*Questions 3 and 6 pertain to the Case Study.  
Each question should be answered independently*

**6.**

(6 points) Refer to section 1.5 of the Case Study.

- (a) (1 point) Big Ben is committed to maintaining a strong capital base to support the risk associated with its business.

Describe one residual risk and one inherent risk that apply to Big Ben. Justify your response.

ANSWER:

- (b) (2 points) Big Ben is implementing the Model Governance framework.

- (i) Define the three major types of internal controls.

ANSWER:

- (ii) Provide an example of an internal control used by Big Ben in the Model Governance framework, for each type you identified in part (i).

ANSWER:

**6. Continued**

(c) (3 points) Big Ben is formalizing its risk appetite framework.

(i) Describe the three increasingly detailed levels of a risk appetite framework.

ANSWER:

(ii) Provide two examples of risk appetite that Big Ben already utilizes or is considering. Justify your response.

ANSWER:

(iii) Provide two examples of risk tolerances that Big Ben already utilizes or is considering. Justify your response.

ANSWER:

**Questions 7 and 8 pertain to the Case Study and/or extension readings.  
Each question should be answered independently.**

## 7.

(10 points) You are a portfolio manager at Toro Capital, a mid-size hedge fund in the U.S. You are analyzing the stock returns of SmartCo, a young company in the technology sector. Your analyst obtains the quarterly returns of SmartCo over the prior calendar year, as shown below:

Q1	10%
Q2	-7%
Q3	-5%
Q4	21%

The analyst notes that SmartCo's stock price achieved a historical peak at the end of Q1 before a new peak was achieved at the end of Q4.

(a) (3.5 points) Calculate the following based on the observed returns. Show your work.

(i) Sharpe ratio, assuming a risk-free rate of 2%.

*The response for this part is to be provided in the Excel spreadsheet.*

(ii) Sortino ratio, assuming a minimum acceptable return of 0%.

*The response for this part is to be provided in the Excel spreadsheet.*

(iii) Return over maximum drawdown.

*The response for this part is to be provided in the Excel spreadsheet.*

## 7. Continued

(b) (3 points) Justify the appropriate performance metric from part (a) to use in each of the following scenarios.

(i) You believe that observed loss patterns over longer periods of time are the best proxy for actual exposure.

ANSWER:

(ii) You believe that risk-adjusted return should not be negatively affected in periods of outsized positive performance.

ANSWER:

(iii) You believe that an investment strategy that is expected to earn the risk-free rate should have a risk-adjusted return of exactly zero.

ANSWER:

You assign your analyst to compare SmartCo's historical returns against those of NGN, another company currently in the portfolio. Your analyst makes the following statements:

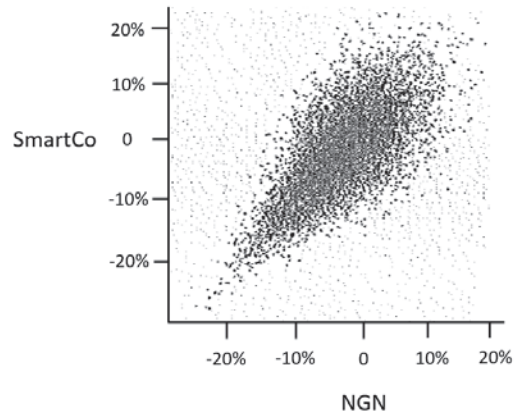
- I. If I can fit marginal distributions to SmartCo's and NGN's returns individually, I will have the information I need to jointly model SmartCo's and NGN's returns in a Monte Carlo simulation.
- II. Under the simplifying assumption that SmartCo and NGN returns jointly follow an elliptical distribution, a correlation coefficient of zero will imply that the returns are independent.

(c) (2 points) Critique your analyst's statements.

ANSWER:

## 7. Continued

Your analyst gathers data for the joint historical returns of SmartCo and NGN, and produces a graph of the data as follows:



- (d) (1.5 points) Assess whether correlation is an appropriate measure of dependency for the two companies' returns. Justify your response based on analysis of the graph.

ANSWER:

**Questions 7 and 8 pertain to the Case Study and/or extension readings.  
Each question should be answered independently.**

## 8.

(10 points) Refer to the November 27, 2021 memo from Max Hawke referencing VA GMWB - New Fund (Case Study section 4.9). You are the investment actuary completing the risk study for Max.

You have collected the following information for your analysis.

- The portfolio's benchmark is the S&P 500 index.
- The current value of the index is 4,000.
- The portfolio Beta is 1.2.
- The risk-free rate is 2%.
- The index volatility is 20%.
- There is no dividend.
- Each option contract represents 100 shares of the index.
- Assume a portfolio of \$1,000,000.

You want to evaluate the cost of purchasing portfolio insurance using options so that the portfolio won't lose more than \$50,000 in one year.

- (a) (0.5 points) Calculate the number of put option contracts required. Show your work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (b) (1 point) Calculate the strike price of the options. Show your work.

*The response for this part is to be provided in the Excel spreadsheet.*

- (c) (3 points) Calculate the total cost of the put options. Show your work.

*The response for this part is to be provided in the Excel spreadsheet.*



## 8. Continued

You have purchased the options from an investment bank. The trading desk of the investment bank wants to delta hedge the risk of the options. Assume:

- The delta hedge is put on at the time of purchase and there is no rebalancing.
- After 1 year, the value of the index will increase to 4,400.

(d) (0.5 points) Calculate the delta on a single put option at time 0. Show your work.

*The response for this part is to be provided in the Excel spreadsheet.*

(e) (1 point) Describe how the cost arises from a delta hedge.

ANSWER:

(f) (3 points) Calculate the cost of the delta hedge after one year. Show your work.

*The response for this part is to be provided in the Excel spreadsheet.*

(g) (1 point) Recommend a method to improve the performance of the hedge. Justify your answer.

ANSWER:

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