

# Exam ERM-INV

**Date:** Monday, October 26, 2020

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## 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 5 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) Individual exams may provide additional directions that apply throughout the exam or to individual items.
2. The answer should be confined to the question as set.
3. The Word and Excel files that contain your answers must be uploaded before time expires.

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## **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.** (7 points) Great Energy Drink (GED) is a global consumer goods company that sells flavored energy drinks via vending machines. GED wants to assess the risk that arises from drinks spoiling due to vending machine failure.

GED has compiled the following data:

- 50 years of aggregate annual loss data
- 24 months of operational failure data
- 10 years of monthly operational losses

- (a) (1 point) GED's ERM team proposes calculating the level of aggregate losses using raw empirical analysis. You are given the following information:

- GED has 50 years of annual data
- Target risk tolerance is based on the VaR(99.5) for a one-year time horizon

Assess whether GED should proceed with this approach.

ANSWER:
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## 1. Continued

(b) (3 points) To model the operational risk associated with vending machine failure, GED's ERM team proposes the following three approaches:

1. Use the most recent 24 months of GED's operation failure frequency and loss severity data, which has been collected by the GED's Data Management Team using a systematic process.
2. Use the most recent 10 years of operation failure frequency and loss severity data from Coca-Cola's media reports. Coca-Cola uses vending machines similar to GED's to distribute products, but it is much larger in size.
3. Use the most recent 24 months of GED electrician logs of machine failures and notes on losses. The data collection process by electricians on duty may not be robust, but the loss severity will be estimated based on reasonable inferences using notes.

Assess each of the three approaches.

ANSWER:
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(c) (3 points) The ERM team has compiled monthly operational losses from GED's vending machines. The table below shows the 15 worst months over the last 10 years.

## 1. Continued

Month	Operational Losses	ERM Team's Notes
December 2017	\$2,246	Unauthorized activity occurred resulting in loss of inventory
November 2018	\$4,493	Unauthorized activity occurred resulting in loss of inventory
January 2017	\$9,033	System breakdown causing sales for the last 10 days of the month to not be recorded
December 2018	\$12,292	Access to machines was reduced due to road closures
May 2015	\$12,925	GED expanded the business to Brazil, and sales data for Brazil has been added for the first time
January 2018	\$14,100	Unauthorized activity occurred resulting in loss of inventory
December 2019	\$16,118	Unauthorized activity occurred resulting in loss of inventory
December 2011	\$16,328	Multiple routine execution errors occurred in the month due to lack of staff training and unauthorized activity resulted in loss of inventory
November 2014	\$16,656	Multiple routine execution errors occurred in the month due to lack of staff training and unauthorized activity resulted in loss of inventory
March 2012	\$16,886	GED expanded the business to Canada, and sales data for Canada has been added for the first time
February 2015	\$17,907	Multiple routine execution errors occurred in the month due to lack of staff training
December 2013	\$18,237	Multiple routine execution errors occurred in the month due to lack of staff training
October 2013	\$19,133	Multiple routine execution errors occurred in the month due to lack of staff training
November 2011	\$19,140	Sales data for Japan only; data for other regions were not recorded for the month.
December 2014	\$19,157	GED expanded the business to Thailand, and sales data for Thailand has been added for the first time

## 1. Continued

- (i) Calculate the monthly VaR(95) and CTE(95) of the operational losses for running the machines using the historical method.

ANSWER:

- (ii) Evaluate quality of data provided in the ERM team's notes for operational risk modeling. Justify your response.

ANSWER:

2. (12 points) You are a risk analyst at BlueSky Airlines working for Elon, the CEO, to analyze risks arising from the company's operations.

BlueSky is a carrier based in the United States with multiple daily flights across the U.S., Europe and the Caribbean.

BlueSky recently invested to modernize aircrafts in its aging fleet. Funds were raised by issuing bonds.

BlueSky's expenses have increased from last year due to higher repair costs, higher than expected oil prices, and expenditures in carbon reduction initiatives.

Elon is concerned with exchange rate fluctuations because a large portion of revenues are denominated in Euros, but expenses are denominated in U.S. Dollars.

- (a) (2 points) Elon has identified the following risks:

- Engine failures due to mechanical or software issues
- Climate change
- Fuel price volatility

Current risk mitigation approaches include:

- Use of insurance
- Use of derivatives
- Transferring costs caused by service disruption to customers by raising ticket prices.

- (i) Explain how each risk is relevant to BlueSky's operations.

ANSWER:

- (ii) Explain how BlueSky's risk mitigation approaches could be used to address the identified risks. Justify your answer.

ANSWER:

## 2. Continued

- (b) (4 points) To hedge against an unexpected rise in interest rates, BlueSky proposes implementing a duration-based hedging strategy using futures.

You use the reference portfolio below as a proxy for BlueSky's debt exposure. The total portfolio value is 100 million USD.

	<b>Bond 1</b>	<b>Bond 2</b>
Allocation %	50%	50%
Term (in years)	1	3
Annual Coupon	2.00%	3.00%
Price	1,005	986
Yield	1.50%	3.50%
Redemption Value	1,000	1,000

To hedge your risk, you plan to enter an offsetting position on interest rate futures contracts, which will expire in three months, to deliver U.S. Treasury Bonds in exchange for cash.

The number of contracts that should be entered into is given by the following formula, with the parameters described in the table below.

$$N = \frac{PVBP_p}{PVBP_h}$$

<b>Parameter</b>	<b>Description</b>	<b>Value</b>
$PVBP_p$	Change in BlueSky's reference portfolio value resulting from a 1 basis point change in gross redemption yield	?
$PVBP_h$	Change in value of 1 interest rate futures contract resulting from a 1 basis point change in the interest rates	94.108

- (i) Calculate the modified duration and convexity of each bond and for the reference portfolio. Show all work.

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

- (ii) Determine the number of futures contracts BlueSky should enter into. Show all work.

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



## 2. Continued

- (iii) Describe the shortcomings of this hedging strategy.

ANSWER:

- (c) (6 points) BlueSky expects to receive a revenue payment of 100 million EUR in six months. BlueSky's treasury department wants to lock in the transaction at the current six-month forward exchange rate of 1.5 USD/EUR.

You are exploring two potential strategies to hedge against exchange rate risk:

**Strategy A:** Enter into a forward contract to deliver 100 million EUR at 1.5 USD/EUR in six months

**Strategy B:**

- Notional amount: 100 million EUR
- Buy a six-month European put option with exercise price of 1.49 USD/EUR
- Sell a six-month European call option with exercise price of 1.51 USD/EUR

Your assistant used a Monte Carlo method to estimate the risk-neutral payoff of each option in Strategy B but only recorded the results of the first 99 simulations. He provided the following information about the simulation:

- Sample size = 100
- Assume the exchange rate at time  $T$  follows the stochastic process given by:

$$S(T) = S(0)e^{\left(\mu - \frac{\sigma^2}{2}\right)T + \sigma\epsilon\sqrt{T}}$$

- $\mu = 0.05$
- $\sigma = 0.3$
- Risk-free rate = 0.05 compounded continuously
- Cost: 2.5 bps of notional amount per transaction
- Final  $N(0,1)$  simulated value from the sample is 0.065
- Average value of the risk-neutral payoffs for the first 99 simulations:
  - For the put option, 0.0806
  - For the call option, 0.0756

## 2. Continued

- (i) Calculate the expected risk-neutral payoff of each option under Strategy B. Show all work.

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

- (ii) Determine the total cost of Strategy B. Show your work.

ANSWER:

- (iii) Elon says that Strategy A is more appropriate as there is no cost of entering a forward contract. Critique his assertion.

ANSWER:

Six months later the USD/EUR exchange rate is 1.52.

- (iv) Calculate the profit or loss of this hedge under each strategy, relative to an unhedged position, assuming cash flows are accumulated at the risk-free rate. Show all work.

ANSWER:

3. (9 points) You are an actuary working for Island Life (IL), an international insurance company. IL has begun selling a new 5-year term life insurance contract with large face amounts to high net worth clients around the world. This is a new market for the company, experience data has been hard to obtain, and IL does not plan to reinsure this product. The company plans to report the financials of these contracts under the scope of IFRS 17.

You have developed a stochastic cash flow model to help set the economic capital requirement for this new product. Mary, your boss, suggests that a CTE measure should be used as a risk metric. You note that VaR is also frequently used in practice.

- (a) (1 point) Describe two reasons why it may be appropriate for IL to use VaR instead of CTE as a risk measure for its economic capital calculation.

ANSWER:

- (b) (2.5 points) Your team has decided to use VaR(99) to set the capital amount. Mary agrees but mentions that a risk adjustment should be added to the calculation using the cost-of-capital approach under IFRS 17. The model output is shown in the table below.

Year	Undiscounted End of Period Expected Value of Future Liability Cash Flow (\$ million)	99% Confidence Level Liability Cash Flow (\$ million)
1	23,150	32,410
2	17,560	23,710
3	12,510	16,260
4	8,070	10,120
5	4,250	5,100

Assume IL's cost-of-capital rate is 6.0% and a risk-free discount rate of 1.8%.

- (i) Calculate the total risk adjustment for the term insurance product using the cost-of-capital technique according to IFRS 17. Show all work.

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

### 3. Continued

- (ii) Interpret what this risk adjustment would represent for IL's shareholders.

ANSWER:

- (iii) Describe two alternative approaches that could be used to calculate the risk adjustment under IFRS 17.

ANSWER:

- (c) (2 points) IL's CRO has reviewed your results and is uncomfortable with the cost-of-capital rate used in the risk adjustment calculation for the new term life business. Based on her experience, she says it should be higher than the 6% that IL uses for other blocks of business.

Evaluate the CRO's assertion.

ANSWER:

- (d) (1.5 points) IL wishes to establish a robust validation process to ensure that the results are accurate and calculated in accordance with IFRS 17 guidelines. Mary wants you to develop additional validating procedures beyond just validating the model output.

Describe three general validation aspects that could be implemented into the framework.

ANSWER:

### 3. Continued

- (e) (2 points) After four reporting cycles, IL's management has raised concerns regarding the volatility of the reported economic capital for the new term product. In response, Mary suggests the following methods to help explain the volatility of the final results:

- I. Sensitivity Testing
- II. Analysis of change in risk adjustment
- III. Benchmarking or Proxies

Assess the appropriateness of each method for analyzing IL's term business.

ANSWER:
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4. (12 points) Company XYZ, a life insurer, has the following credit risk appetite statement (RAS) with regards to its investment strategy:

“The company will not invest in any bonds that have a credit rating below A, and the company expects its assets and liabilities to be matched within 0.1 years on a Key Rate Duration basis.”

XYZ has recently experienced credit losses in its bond portfolio that it thought would not occur given its RAS. XYZ’s current asset allocation is shown in the table below.

<b>Bond Rating</b>	<b>Market Value of Assets (\$ million)</b>
AA	27
A	15
BBB	0
<b>Total</b>	<b>42</b>

- (a) (3 points)
- (i) Define three risk factors of credit risk related to an asset portfolio.
  - (ii) Identify which credit risk factor is the most likely driver of the unexpected losses given XYZ’s compliance with its RAS. Justify your response.
  - (iii) Explain why XYZ is still exposed to credit risk, even if it complies with its RAS.
  - (iv) Recommend an additional requirement XYZ could add to its RAS that would account for the risks identified in part (iii). Justify your response.

ANSWER:

#### 4. Continued

- (b) (5 points) The following table shows the one-year credit migration probabilities for bonds with various ratings.

		Year-end Rating (%)				Recovery Rate
		AA	A	BBB	Default	
Initial Rating (%)	AA	85	13	2	0	40%
	A	12	82	4	2	25%
	BBB	5	10	76	9	20%

- (i) Calculate the expected credit losses from default in the next year using the credit migration model. Show all work.

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

- (ii) Calculate the expected amount of bonds that need to be sold after one year in order to satisfy the RAS. Show all work.

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

- (iii) Explain a source of portfolio losses, other than defaults, that is captured in the credit migration model.

ANSWER:

#### 4. Continued

(c) (4 points) A portfolio manager determines XYZ's expected losses based on the Merton model, and you notice the results are different than the losses you calculated in part (b)(i).

(i) Explain how each input used in the Merton model affects the calculated probability of default.

ANSWER:

(ii) Explain why the differences between the credit migration model and the Merton model could result in different estimated defaults.

ANSWER:

(iii) Recommend which model XYZ should use going forward in order to address XYZ's unexpected losses. Justify your response.

ANSWER:



**Questions 5 and 6 pertain to the Case Study.  
Each question should be answered independently**

- 5.** (10 points) Caerus Consulting (CC) has been hired by Big Ben Bank to assess its strategic plan. You work for CC and have been asked to assist with this project.

Refer to section 0.7 of the Case Study.

- (a) (4 points) Big Ben's strategic plans include the expansion of its Asset Management Business client base by lowering the minimum investable assets requirement. Big Ben also plans on formulating a one-stop shopping interface for its globally mobile clientele.

Assess how this strategy may affect Big Ben's:

- I. Strategic risk
- II. Business risk and its impact on profitability
- III. Operational/technology risk in general and cybersecurity risk in particular

ANSWER:

- (b) (3 points) Big Ben is weighing a choice between retaining and transferring cybersecurity risks that would arise from the expansion strategy.

- (i) Describe the advantages and disadvantages of:

- Retaining cybersecurity risk internally
- Transferring cybersecurity risk externally.

ANSWER:

- (ii) Recommend a mitigation / control option for each choice. Justify your response.

ANSWER:

## 5. Continued

(c) (3 points) As part of Big Ben's strategy to expand its Investment Banking business, the company decided to transfer cybersecurity risk and plans on utilizing a Special Purpose Vehicle (SPV) as a way for its clients to raise capital and transfer specific risks.

(i) Explain how an SPV could be structured to meet Big Ben's goal.

ANSWER:

(ii) Assess the benefits and risks to Big Ben of this particular mitigation option. Justify your answer by using information from the Case Study.

ANSWER:

**Questions 5 and 6 pertain to the Case Study.  
Each question should be answered independently**

**6.** (10 points) Disruptive Energy (DE) wants to expand into the autonomous vehicle market and become the leader in this technology. DE is considering hiring Caerus Consulting (CC) to identify its key risks over the next three years in achieving this goal. Refer to sections 0.1 – 0.6 and 0.10 of the Case Study.

(a) (1 point) Recommend whether CC is an appropriate company for DE to hire to perform the risk analysis based on CC’s overview in the Case Study. Justify your response.

ANSWER:

(b) (3 points) An actuarial analyst at CC provides the following comments as part of the SWOT analysis for DE entering this new market.

- “(Strength) DE can quickly update all car systems via existing internet connections
- (Weakness) The market does not appear to be requesting artificial intelligence (AI) right now
- (Opportunity) Autonomous technology could easily be added to new products as they roll them out
- (Threat) DE currently doesn't have the expertise in house right now.”

(i) Critique the comments provided.

ANSWER:

(ii) Provide one additional item for each SWOT component.

ANSWER:

## 6. Continued

DE wants to indemnify (\$500,000 per life) on behalf of each person who dies in accidents caused by defective AI.

- (c) (3 points) The following three options for managing the risk associated with the indemnity plan were identified:
- Do nothing to mitigate the risk
  - Set up a captive to insure this risk
  - Buy insurance coverage from a third party

Evaluate each of these options for DE.

ANSWER:

- (d) (3 points) A decision was made to purchase insurance. The following insurance structures are under consideration:
- Insurance that covers all life insurance losses
  - Insurance that covers losses on a 50% quota share basis
  - Excess of loss insurance above a fixed annual limit of \$X

Recommend which structure to implement.

ANSWER:

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

**7.** (13 points) Please refer to Case Study section 0.11.

Caerus Consulting has been engaged by Energetix to evaluate the investment strategy of the pension plan. The company's objective is to earn a high rate of return while minimizing the risk of being required to make a contribution.

Caerus wants to study the impact of investing the pension assets fully in a US stock portfolio.

- The modified duration of the pension liabilities is 15 years
- The asset portfolio beta = 1.2
- Annual volatility of the S&P 500 index: 12%
- The 1-year US Treasury rate is 2%.

You assume the following:

- Net cash flows for 2020 are zero
- The yield curve is expected to experience a 1% level increase for 2020
- Expected return of the S&P 500 index: 9%
- The only change in the liability value is due to interest rates.

(a) (2 points) Calculate the expected surplus return for 2020, as a percentage of the initial asset value. Show your work.

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

## 7. Continued

Caerus considers a portfolio allocation approximated by investing the assets in the following 3 stocks. Stock 1 and Stock 2 have equal allocations in the portfolio, with the remaining allocation in Stock 3. Caerus wants to maintain the same target portfolio beta of 1.2.

	Beta ( $\beta$ )	Volatility ( $\varepsilon$ )
Stock 1	0.7	2%
Stock 2	2.0	4%
Stock 3	1.1	7%

(b) (3 points)

(i) Calculate the volatility of the asset portfolio. Show your work.

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

(ii) Critique the use of the model used in (i) to estimate volatility.

ANSWER:

## 7. Continued

Caerus wants to optimize the surplus volatility of the pension plan. Assume the following:

- Volatility of changes in yields is  $\sigma_y = 1\%$  annually
- Correlation between asset and liability =  $-0.1$
- Normal distribution of stock returns.

(c) (5.5 points)

- (i) Calculate the 95th percentile of the expected surplus position at 12/31/2020. Show your work.

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

- (ii) Describe the relationship between asset-liability correlation and the funding risk of the pension plan.

ANSWER:

- (iii) Assume the correlation between asset and liability is now 0.95. All other variables remain unchanged.

Calculate the optimal funding ratio (A/L) to minimize surplus volatility. Show your work.

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

## 7. Continued

Energetix wants to move forward with investing its pension assets in common stock. The Chief Investment Officer would like to allocate the \$50 million held in US stocks to its two active managers by maximizing its overall information ratio, subject to a portfolio tracking error volatility (TEV) of 3.5%. You are given:

- The information ratio for manager A is 0.8
- The information ratio for manager B is 0.5
- The TEV for each manager is 5%.

(d) (2.5 points)

(i) Calculate the portfolio weight for each manager. Show your work.

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

(ii) Calculate the overall portfolio information ratio. Show your work.

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



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

**8.** (7 points) You are an analyst in the investment department of a large insurance company. You wish to simulate a collateralized debt obligation (CDO) after calibrating your copula to fit market prices.

(a) (2 points)

(i) Describe the steps necessary to simulate a loss distribution given random variables  $X_1, X_2, \dots, X_n$  with distributions  $F_1, F_2, \dots, F_n$ , and a copula  $C(u_1, \dots, u_n)$ .

ANSWER:

(ii) Compare and contrast the use of rank correlation and linear correlation for copula calibration.

ANSWER:

## 8. Continued

The company is considering purchasing two CDOs – CDO A and CDO B. You have been asked to assess their risks.

CDO A contains 100 equally-weighted, investment-grade issuers. You are given the market prices for the three tranches. Using the one-factor Gaussian copula model, you calculate the correlation needed to replicate the market prices for each tranche, as shown:

Seniority	Correlation
Equity	20%
Mezzanine	18%
Senior	25%

Your coworker reviews your results and states:

1. The underlying default dependence structure is not a function of tranche seniority.
  2. The correlations should be identical for all tranches.
- (b) (1 point) Critique your coworker's statements.

ANSWER:
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## 8. Continued

CDO B contains 20 equally-weighted issuers. Historical data indicates that this CDO has the following properties:

- Asymmetric default risk, as the issuers are clustered around certain locales/industries
- High tail dependence between the bond issuers

To model defaults on a tranche from this CDO, you are considering the following copulas:

1. Gaussian Copula
2. Student- $t$  Copula
3. Gumbel Copula

- (c) (1.5 points) Assess the appropriateness of each copula to quantify the risks of this CDO.

ANSWER:

Your manager is concerned with risks similar to those faced by public firms in the 2008 Financial Crisis and has asked you to perform a broader scenario-based risk analysis.

- (d) (0.5 points) Describe one advantage and one disadvantage of evaluating risks using scenario-based aggregation.

ANSWER:

## 8. Continued

The company has set the following objectives should a similar financial crisis occur:

- Limit the exposure to loss from credit defaults
- Maintain sufficient liquidity to be able to act on potential acquisition opportunities during a crisis.

You are developing actions that can be taken to meet the above objectives. In doing so, you take note that your firm has a substantial long position in mezzanine tranches.

You are considering the following potential actions:

1. Sell protection on super-senior tranches instead of mezzanine tranches
2. Reduce the allocation in CDOs and purchase treasuries
3. Purchase credit default swaps (CDS) (i.e., buy protection) for hedging

- (e) *(1.5 points)* Assess the effectiveness of each action in meeting the company's objectives.

ANSWER:

- (f) *(0.5 points)* Recommend the most appropriate action. Justify your recommendation.

ANSWER:

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