Exam QFIIRM

Date: Friday, May 5, 2023

INSTRUCTIONS TO CANDIDATES

General Instructions

1. This examination has 11 questions numbered 1 through 11 with a total of 60 points.

   The points for each question are indicated at the beginning of the question.

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.
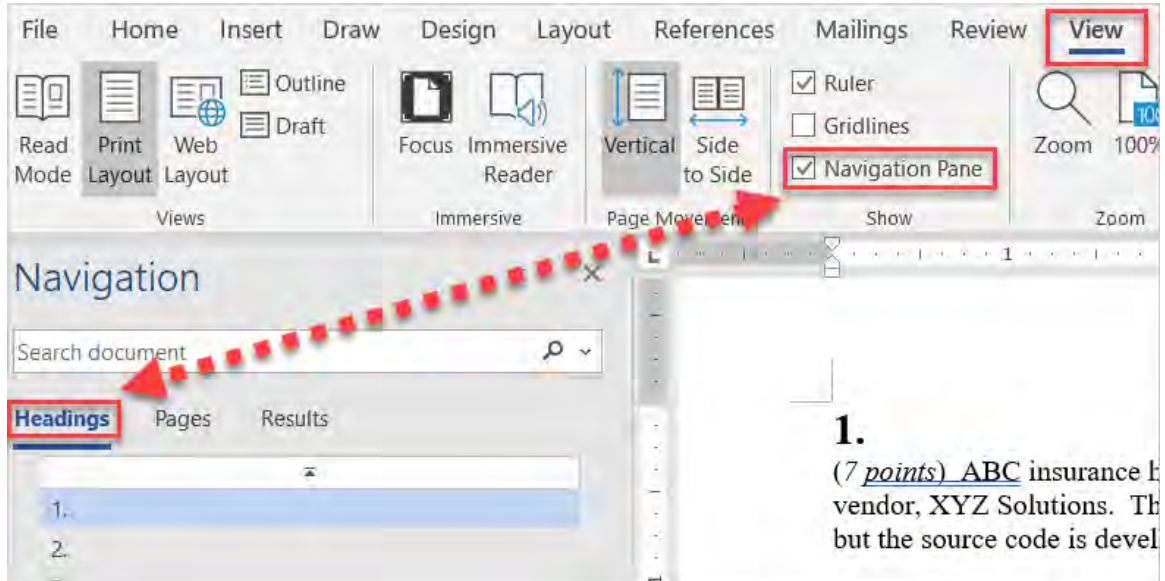
Written-Answer Instructions

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, β_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. 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 time expires.

Navigation Instructions

Open the Navigation Pane to jump to questions.

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

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1.

2.

1.

(*7 points*) ABC insurance h
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1.

(*6 points*) The company's Chief Risk Officer (CRO) is considering using prospect theory to replace the traditional expected utility theory to make a decision. She would like to carry out a pilot project to evaluate two investment strategy prospects.

(a)   (*1.5 points*) Explain the differences between expected utility theory and prospect theory in terms of

(i)   reference points

ANSWER:

(ii)   value function

ANSWER:

(iii)   weighting function

ANSWER:

Prospect I, the potential payoffs, and associated objective probabilities

Scenarios (j)	Potential Payoff (x_j) in millions	Objective Probabilities	Subjective Probabilities
1	-4000	0.005	0
2	-200	0.3	0.25
3	-5	0.2	0.25
4	100	0.3	0.25
5	600	0.19	0.25
6	12000	0.005	0

Prospect II, the company receives $50 million with probability of 1.0.

1. Continued

Assume the company's initial wealth is $6 billion. The company's utility function is

$$u(w) = -\frac{10{,}000}{w}$$

and the value function is

$$v(x^*) = \begin{cases} (x^*)^{\alpha} & x^* > 0 \\ -\lambda((-x^*)^{\beta}) & x^* \le 0 \end{cases}$$

Where
$$\lambda = 2.0$$
$$\alpha = \beta = 0.9$$

Assume the reference point is the company's initial wealth.

(b) (*2 points*) Determine which prospect gives the higher subjective value under the prospect theory.

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

The CRO thinks it's more appropriate to reframe the decision by re-evaluating the prospects, assuming that the reference point is initial wealth + $50million.

(c) (*2.5 points*)

    (i) (*0.5 points*) Explain why the CRO thinks reframing the decision is more appropriate.

> ANSWER:

    (ii) (*1 point*) Determine which prospect gives a higher subjective value under the new reference point.

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

    (iii) (*1 point*) Explain the difference in decision, if any, between part b and part c(ii).

> ANSWER:

2.

(*8 points*) Company ABC is selling a product with a guaranteed minimum accumulation benefit (GMAB) rider. The account value of this product is based on Stock Index S. However, the rider guarantees that the payoff after 10 years will be equal to the initial premium or the account value at that time, whichever is greater.

ABC would like to model the economic capital for this product using the following information:

- Losses mimic a put option:
  $L = 10{,}000 \max (1 - S_{10}, 0)$, where S_{10} is the price at time 10 of an underlying equity investment, with initial value $S_0 = 1$.
- By using historical data, ABC estimates $S_{10} \sim e^Y$ where Y is a normal distribution $N(\mu, \sigma)$ where $\mu = 1$, $\sigma = 0.7$
- ABC is considering using either VaR or Expected Shortfall as the risk measure for calculating economic capital.

(a)   (*1 point*)

   (i)   (*0.5 points*) Calculate the probability of a loss for the product.

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

   (ii)   (*0.5 points*) Calculate the 95% VaR of loss L.

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

Let

$Q_{1-\alpha}^S$ denotes the $1 - \alpha$ quantile of the S_{10} distribution

$f_S(y)$ denotes the lognormal probability density function of the S_{10} distribution

$$f_S(y) = \frac{1}{\sqrt{2\pi}\sigma y} e^{-\frac{1}{2}\left(\frac{\ln(y)-\mu}{\sigma}\right)^2}$$

2. Continued

Assume the probability of loss is from part a(i).

(b)   (*2 points*) Calculate the 90% and 95% Expected Shortfalls for the product.

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

ABC decided to reinsure any loss greater than VaR 95%, essentially limiting their loss from the product to VaR 95%.

(c)   (*0.5 points*) Calculate the expected loss for ABC net of reinsurance $E[\min (L, Q_\alpha)]$.

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

(d)   (*2.5 points*)

   (i)   (*1 point*) Calculate the smoothed empirical estimate for VaR 95% from the Monte Carlo simulation presented in the Excel Spreadsheet.

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

   (ii)   (*1 point*) Calculate the 90% confidence interval for VaR 95% from the Monte Carlo simulation presented in the Excel Spreadsheet using the order statistics method. Interpolate between the integer value of the order statistics losses to get the results.

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

   (iii)   (*0.5 points*) Describe the advantages and disadvantages of the order statistics method vs. repeat simulation method for calculating confidence intervals.

> ANSWER:

2. Continued

(e) (*2 points*)

    (i)   (*0.5 points*) Calculate the Expected Shortfall $\widehat{ES_{95\%}}$ from the Monte Carlo simulation presented in the Excel Spreadsheet.

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

    (ii)   (*0.5 points*) Critique the use of sample standard deviation $\frac{s_u}{\sqrt{N(1-\alpha)}}$, where s_u is the standard deviation of the upper $100(1-\alpha)\%$ of the simulated losses.

> ANSWER:

    (iii)   (*1 point*) Calculate the standard deviation of the Expected Shortfall $\widehat{ES_{95\%}}$ using the Manistre-Hancock formula.

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

3.

(*5 points*) You are a consultant specialized in stress testing for insurance companies.

(a)   (*1 point*) Identify four uses of stress testing on investment portfolio.

> ANSWER:

You begin stress testing for company XYZ and ask for input from employees who design insurance products.

- Employee A recommends stressing the interest rate in isolation by 1-2 basis points, which is a typical movement in the interest rate.
- Employee B recommends stressing the interest rate by 1000-2000 basis points while also stressing the tax rate on bonds.
- Employee C recommends stress testing based on the market conditions during the 2020 pandemic.

(b)   (*2 points*) Critique each of the employees' recommendations.

> ANSWER:

Now you assess company QRS, which uses stress testing to evaluate risks in their models. You collect the following information on the firm's use of stress testing:

- The objectives of the stress tests were determined by the Chief Risk Officer (CRO) and shared with the Board.
- The stress tests were used to ensure compliance with regulatory frameworks.
- The CRO reviews the results of the stress test and examines the model framework annually.
- Employees seem dismissive of the results, with one commenting "such events would never occur and modeling their impact is a waste of time."

3. **Continued**

(c) (*2 points*)

(i) Critique the firm's current use of stress testing.

ANSWER:

(ii) Recommend three changes the firm can implement to more effectively utilize stress testing.

ANSWER:

4.

(*8 points*) ABC Life Insurance company has a portfolio composed of funds to support an indexed universal life block of business. The current portfolio consists of:

- 1 million shares of Fund X
- 5 million shares of Fund Y
- 10 million shares of Fund Z

The previous week's daily closing price, volume, and shares outstanding are given below.

Day of Week	Fund X Price ($)	Fund X Volume	Fund Y Price ($)	Fund Y Volume	Fund Z Price ($)	Fund Z Volume
Monday	105.00	15,000,000	45.00	6,800,000	5.00	7,936,000
Tuesday	100.00	16,000,000	41.00	6,960,000	5.10	7,424,000
Wednesday	110.00	12,500,000	44.00	5,760,000	4.60	9,600,000
Thursday	115.00	22,000,000	42.80	7,440,000	4.90	6,400,000
Friday	95.00	30,000,000	42.00	5,600,000	5.00	5,880,000

	Fund X	Fund Y	Fund Z
Shares Outstanding	1,000,000,000	200,000,000	100,000,000

(a)   (*1 point*) Calculate the current Liquidity Risk for each company on Friday using:

(i)   Liquidity Ratio (LR)

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

(ii)   Hui and Heubel Liquidity Index (HH)

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

4. **Continued**

(b)   (*1.5 points*)

   (i)   (*0.5 points*) Determine the ranking of each fund, from the highest liquidity to the lowest liquidity, using the values calculated in part (a).

   ANSWER:

   (ii)   (*1 point*) Justify your ranking.

   ANSWER:

(c)   (*2.5 points*) Propose a rebalancing portfolio trade to have an expected weighted average liquidity ratio of 250 million based on the Friday close price, subject to the following constraints:

   (i)   No shorted shares are allowed

   (ii)   No remaining cash on hand is allowed

   (iii)   Fractional shares are allowed

   (Goal Seek functionality is available within Excel under the Data tab, What-If Analysis)

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

The Chief Finance Officer (CFO) believes that with the recent rise in inflation and interest rates there will be a decrease in policyholder premiums and an increase in policy surrender rates. The CFO would like to develop two scenarios to understand the risks to the block of business and is considering these two scenarios:

   (i)   Historical Scenario using the 1971 – 1990 US rates

   (ii)   Synthetic Scenario with deterministically generated rates

.
(d)   (*1.5 points*) Describe the key considerations of using historical and synthetic scenarios to understand the liquidity risk of the portfolio.

   ANSWER:

4. Continued

(e) (*1.5 points*) Recommend a modification to improve each scenario.

ANSWER:

5.

(*5 points*) You work at a life insurance company. Your manager asks you to compare some key measures to evaluate the risk of loss for an investment portfolio.

(a) (*1 point*)

(i) Define Value at Risk (VaR) and Expected Shortfall (ES).

ANSWER:

(ii) Identify two advantages of ES over VaR.

ANSWER:

Your manager suggests using a normal distribution of losses to calculate both VaR and ES.

(b) (*1 point*) Describe two advantages and two disadvantages of using this assumption.

ANSWER:

Using the normality assumption, your manager asks you to calculate the expected shortfall for a portfolio which comprises:

- 5 units of Index A, with an initial value $S_A(0) = 150$,
- 8 units of Index B, with an initial value $S_B(0) = 125$, and
- A 3-month call on 10 units of Index A with strike price $K_A = 130$.

In addition, assume that:

- The annual risk-free rate is 2%
- The annual volatilities $\sigma_A = \sigma_B = 15\%$
- Index A and Index B are not correlated
- There are 250 trading days per year
- There are no expected dividends paid

5. Continued

(c)   (*2 points*)

    (i)   (*1 point*) Calculate the value of the portfolio at time 0.

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

    (ii)   (*1 point*) Calculate the 1-day 99% ES of the portfolio using the Delta-Normal method.

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

Your manager wants to calculate the 10-day ES for a different portfolio with derivatives and 10 underlying assets. Your colleague suggests that the Delta-Gamma-Normal method would be appropriate in this case.

(d)   (*1 point*) Critique your colleague's suggestion.

> ANSWER:

6.

(*5 points*) You are an investment actuary working on a portfolio construction team. Your colleague asks for assistance with risk budgeting.

She provides the following information about three assets comprising the total portfolio:

	Asset A	Asset B	Asset C
Portfolio Weight	0.2	0.3	0.5
Volatility	0.3	0.2	0.12

She also provides you the following correlation matrix:

	Asset A	Asset B	Asset C
Asset A	1	0.5	-0.5
Asset B	0.5	1	-0.5
Asset C	-0.5	-0.5	1

Assume the expected return of each asset is zero, and that returns are normally distributed.

(a)   (*1 point*) Calculate the volatility of the portfolio.

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

(b)   (*1 point*) Calculate the marginal volatility and risk contribution of each asset in the portfolio.

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

Your colleague would like additional clarification on the meaning of risk contributions.

(c)   (*1.5 points*) Describe two ways of interpreting risk contributions.

> ANSWER:

6.   **Continued**

Your colleague notes there is a risk budget constraint of 50%, 50%, and 0% for Assets A, B, and C, respectively. Based on these constraints, she believes that respective portfolio weights of 40%, 60%, and 0% are optimal.

(d)   (*1.5 points*)

   (i)   (*0.5 points*) Assess whether your colleague's suggested portfolio meets the risk budget constraints.

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

   (ii)   (*1 point*) Assess whether your colleague's suggested portfolio is the optimal portfolio subject to these constraints.

ANSWER:

7.

(*5 points*) You are an actuarial analyst working in risk management for a life insurance company. Your company is planning to launch a new universal life product and you are responsible for reviewing the product with respect to liquidity risk.

(a)   (*1 point*)

(i)   Define liquidity risk.

ANSWER:

(ii)   Identify key types of cash sources and cash needs for life insurance companies.

ANSWER:

The current liquidity standard states that the minimum required ratio (MRR) is 1.5 over a 30-day horizon.

You are provided a current balance sheet for the company:

Assets	
Cash	1,000
Bond (Book Value)	100,000
Equity (Market)	20,000
Liabilities	
Annuity Reserves	75,000
Life Reserves	25,000

You are also told:

- Overall 30-day liquidity needs for annuity and life lines of business, not considering any incremental needs for the new product, are 3,500 and 1,500 respectively.
- Bond coupons amounting to 5% of book value and equity dividends amounting to 10% of market value are to be received within 30 days.
- Additional cash sources or needs are not utilized in the calculation of the ratio.

7. Continued

(b)   (*1.5 points*) Assess whether the MRR is met.

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

Based on pricing projections, there is going to be an additional 500 of cash needs for the new universal life product over the 30-day horizon. Your manager states that the company has allocated 1,000 of required capital for the product. He argues that after reflecting such capital, the company's liquidity standard will be met.

(c)   (*1 point*)

(i)   (*0.5 points*) Evaluate your manager's assertion.

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

(ii)   (*0.5 points*) Explain your conclusion.

> ANSWER:

When you present your critique, you also note that the current liquidity standard fails to adequately assess and limit liquidity risks.

(d)   (*1.5 points*) Propose four improvements to the liquidity standard.

> ANSWER:

8.

(*4 points*) You are reviewing the credit portfolio at ABC Life Insurance. The company purchased a 5-year Credit Default Swap (CDS) index 2 years ago. The index consists of 125 of the most liquid North American entities with investment grade credit ratings that trade in the CDS market. All 125 entities have the same notional amounts in the CDS.

The following are the trade details of this CDS index:

- Trade date is September 20, 2020
- Maturity date is December 20, 2025
- Coupon is 100 bps
- Coupon payments are quarterly
- Contract notional is $1 million
- Recovery rate is 40%
- Method of settlement is cash settlement

(a)   (*1 point*)

(i)   (*0.5 points*) Explain what "buying the index" means.

ANSWER:

(ii)   (*0.5 points*) Calculate the net cash flow of ABC Life Insurance on September 20, 2021with respect to the CDS index, assuming no default since the inception of the index.

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

8. **Continued**

The credit quality of the index deteriorated over the last 2 years.

(b) (*1 point*) Explain whether the following values change due to the credit deterioration.

(i) Coupon set on the issue date of the CDS index

> ANSWER:

(ii) Upfront value of this CDS index series if you were to enter a position today

> ANSWER:

On November 1, 2021, one of the credits in the reference portfolio experienced a credit event.

(c) (*1 point*)

(i) List the possible "credit events" that will trigger the payment of the CDS protection.

> ANSWER:

(ii) List the steps that the existing index series and the reference credit will need to go through after a credit event.

> ANSWER:

8. **Continued**

(d) (*1 point*) Calculate the net cash flow of ABC Life Insurance with respect to the CDS index on:

(i) November 1, 2021

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

(ii) September 20, 2022

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

9.

(*5 points*) On January 1, 2000, your company sold a line of business for $100M and will receive the full payment in six months at t_1. Your company does not need the money at t_1 but will need it in twelve months at t_2 to fund a capital investment. Your company would like to lock in the interest rate to be applicable on the $100 million receivable for the six-month period from t_1 to t_2.

Assume that interest rates are positively correlated with futures prices.

(a)   (*0.5 point*) Explain whether the price of a futures contract may be different from the price of an otherwise equivalent forward contract.

> ANSWER:

Your firm enters into a 6-month forward rate agreement (FRA) expiring on July 1, 2000 with a bank on January 1, 2000 for the period of July 1, 2000 to January 1, 2001. The current price of the 6-month zero coupon bond is $96.79 and the price of the 1-year zero coupon bond is $93.51.

(b)   (*1 point*)

   (i)   Determine the semi-annually compounded forward rate of the contract.

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

   (ii)   Calculate the value of the FRA at inception.

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

Consider that it's now July 1, 2000. You receive the discount factors Z(0,T) in the following table.

Maturity	July 1, 2000 Z(0,T)
0.25	0.9848
0.5	0.9692
0.75	0.9545
1	0.9402

9. Continued

(c)   (*2 points*)

    (i)   Calculate the value of the FRA on t_1, July 1, 2000.

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

    (ii)   Calculate the current semi-annually compounded spot interest rate.

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

    (iii) Determine the net amount to be paid at the settlement of the FRA on t_2, January 1, 2001and which party will be responsible for it.

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

You are also given that on July 1, 2000, the European Call option and Put option on the 13-week Treasury bill with maturity in 6 months and strike price of $99.12 is priced at $0.2934 and $0.1044, respectively.

(d)   (*1.5 points*)

    (i)   (*0.5 points*) Demonstrate that the securities are priced incorrectly.

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

    (ii)   (*0.5 points*) Recommend a strategy to take advantage of the arbitrage opportunity.

> ANSWER:

    (iii) (*0.5 points*) Determine the net cashflow of d (ii).

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

10.

(*4 points*) ABC is a large public insurance company that offers life and annuity products. You are a portfolio manager at XYZ, the asset management company ABC has used for years.

ABC's ALM team decided to conduct an internal lunch and learn (training) on investment ethics for professionals. You are asked to present the fundamental principles of investment ethics.

(a) (*1 point*) Describe each of the fundamental principles of investment ethics for your audience.

> ANSWER:

Low interest rates have caused the expected yield based on the Investment Policy Statement (IPS) to be too low for ABC's fixed annuity product to be competitive. ABC requests a higher yield, so you temporarily reallocate some fixed income assets to private equities, which also offer higher commissions. However, allocation to private equities is already maxed out at the 5% limit imposed by the IPS.

(b) (*1.5 points*)

> (i) List four considerations when assessing ABC's risk tolerance and thus the type of investments that would be suitable.

> ANSWER:

> (ii) Determine any unethical behaviors in this scenario.

> ANSWER:

> (iii) Recommend any corrective actions.

> ANSWER:

10. Continued

ABC's management anticipates that the upcoming audit may take more time than usual due to the recent resignation of ABC's CFO and recent accounting standards changes. The management devises the following possible action plans:

- Keep the existing auditing firm in place since the primary auditors have been with ABC for the last five years and are familiar with ABC's business.
- Switch to a different auditing firm for both auditing and consulting services as the new firm has expertise in the new accounting standards.
- Ask the auditing firm to skip reporting any accounting discrepancies that were used to alter financial statements within GAAP, as the discrepancies were reported already.
- Hire a member of the board's audit committee as CFO, given his excellent qualifications.

(c)   (*1.5 points*)

(i)   Identify the relevant regulations or laws that management needs to consider in its action plans.

ANSWER:

(ii)   Assess the appropriateness of each action plan.

ANSWER:

11.

(*5 points*) Company PQR announced that it will shut down old factories and build solar-powered, robot-run factories. This plan would cut the workforce for the factories in half, reduce carbon emissions, and decrease production costs after some initial investment costs. As an analyst, you expect this will increase the return on investment (ROI) in the long run, as the products would appeal more to the growing segment of environmentally conscious consumers, and at a lower price.

(a)   (*2 points*) Describe the interests of each of the following stakeholders and explain how this strategy will or will not serve their interests:

(i)   stockholders

> ANSWER:

(ii)   employees

> ANSWER:

(iii)   customers

> ANSWER:

Intrigued by PQR's strategic decision, you extended your review to the company's proxy statements filed with the SEC. You learned the following:

- The total compensation of the executives consists entirely of salary and cash bonuses.
- The compensation committee has increased the cash bonus of the executives every year, based on each year's accounting performance.

11. Continued

(b) (*1.5 points*)

(i) Critique the compensation stucture and its governance.

ANSWER:

(ii) Recommend two other types of compensation that could be appropriate.

ANSWER:

You have gathered the following observations regarding the PQR board:

1) There are nine directors. All are nonmanagement directors, except for the chairman, who is the CEO of the company.

2) There are three committees: Nominating, Compensation, and Audit. Each has three gray directors. The chairman does not serve on any committee.

3) The term of each director is three years, and only a third of them are up for election in any given year.

4) Directors in the Nominating and Compensation committees have served at least two terms.

5) Five of the directors are currently serving on several other companies' boards.

6) The compensation committee met 30 times before the cash bonus approval, while other board committees met 6 times on average.

(c) (*1.5 points*) Assess the effectiveness of the board.

ANSWER:

END OF EXAMINATION