

INSTITUTE OF ACTUARIES OF INDIA
EXAMINATIONS

May 2026

CP2A- Actuarial Modelling

Time allowed: 3 Hours 15 Minutes

Total Marks: 100

Exam Requirements

Q.1) Modelling steps and data checks

Read the background document, which describes the scenarios that need to be modelled and documented for this project. Technical assistance for the modelling work, should you require it, can be found in the Additional Guidance contained in this booklet. No marks will be deducted for the use of this guidance.

Construct a spreadsheet model that produces the following calculations. You should ensure that your spreadsheet contains appropriate self-checks and that you have performed (and documented in the audit trail) reasonableness checks at each stage of your calculations.

- i) Verify that the demand volatility factors provided follow a Normal distribution by carrying out the Jarque-Bera test as described in Additional Guidance A. Carry out appropriate graphical checks to support the assessment. [6]
- ii) Calculate the weekly production capacity (after decline) for crude oil and natural gas over 80 weeks. [2]
- iii) For the Base Scenario, carry out the following weekly projections:
 - a) Weekly Demand, sales volumes, and storage for each product, ensuring that the storage constraint and the excess capacity disposal mechanism described in the background are correctly applied. [5]
 - b) Revenue in INR for each product (including any revenue from excess capacity disposed of at a discount). [2]
 - c) Weekly costs comprising: production costs, and storage costs (fixed and variable) for each product. [2.5]
 - d) Weekly gross profit and Present value of Gross Profit [1.5]
- iv) For the Stress Scenario (Geopolitical Shock), repeat the calculations in Q1(iii) incorporating the crude oil export blockage and other parameter changes described in the background:
 - a) Phase 1: Acute Shock (Weeks 10 to 25) [5]
 - b) Phase 2: New Normal (Week 26 onwards) [3]
- v) Construct suitable charts showing:
 - a) Present Value of Gross profit over 80 weeks under both scenarios. [2]
 - b) Crude oil storage levels over 80 weeks under the both scenario. [2]
 - c) Natural Gas storage levels over 80 weeks under the both scenario. [2]

[Note: all scenarios outlined above should be modelled separately in your spreadsheet]

[33 marks]**Q. 2) Modelling technique and practice**

- i) Auto checks or reasonableness checks on the modelling completed in (Q.1). **[5]**
- ii) Demonstration of good modelling techniques and practice. **[7]**

[12 marks]**Q.3) Audit trail**

Produce an audit trail for your spreadsheet model that includes the following aspects:

- Purpose of the model
- Data and assumptions used
- Methodology, i.e., description of how each calculation stage in the model has been produced
- Explanation of checks performed

You should ensure that your audit trail is suitable for both a senior actuary, who has been asked to approve your work, and a fellow student, who has been asked to peer review and correct your model, to continue work on it or to use it again for a similar purpose in the future.

Marks available for audit trail:**Audit approach**

- i) Communication skills (the audit trail provides enough detail to be read as a stand-alone document). **[4]**
- ii) Fellow students can review and check methods used in the model. **[7]**
- iii) Senior actuary can scrutinize and understand what has been done. **[7]**
- iv) Written in clear English. **[4]**
- v) Written in a logical order. **[3]**

Audit content

- vi) All steps clearly explained. **[8]**
- vii) Clear signposting included throughout. **[4]**
- viii) Statement of assumptions made. **[5]**
- ix) All model steps accurately covered. **[13]**

[55 marks]**Background**

Bharat Offshore Energy Ltd (BOEL) is an Indian upstream energy company operating an offshore block in the western continental shelf. The block produces both crude oil and natural gas from a shared production facility. The company has a total initial production capacity that is allocated between the two products in a fixed proportion decided by the Board.

Crude oil is exported to international markets via tanker shipments routed through the Strait of Hormuz. Revenue from crude oil sales is denominated in USD. Natural gas is supplied to the domestic Indian market via an undersea pipeline connected to the national gas grid. Revenue from natural gas is denominated in INR.

The Board is concerned about the potential financial impact of a geopolitical escalation in the Persian Gulf region that could disrupt shipping lanes through the Strait of Hormuz. Such an event would severely impact crude oil exports while leaving gas operations largely unaffected.

You work for RKS Actuarial Consultants. Your manager has asked you to build a weekly projection model over 80 weeks under two scenarios and document your work in an audit trail.

Production Data

Parameter	Value
Total initial production capacity	120,000 barrels equivalent per week
Initial allocation to crude oil	70%
Initial allocation to natural gas	30%
Annual production decline rate	10% per annum

Natural gas production capacity is expressed in barrel of oil equivalent (BOE) units. The production capacity decreases every week as the resources deplete. The annual decline rate applies to both products and must be converted to a weekly rate using appropriate discounting.

Note: Production will be done up to the technical capacity, irrespective of demand or inventory.

Storage Data

Parameter	Crude Oil	Natural Gas
Maximum storage capacity	50,000 barrels	15,000 BOE
Inventory levels at the Facility Storage at start of Week 1	30,000 barrels	10,000 BOE
Fixed storage cost per week	INR 4 million	INR 1.5 million
Variable cost per unit per week	INR 40 per barrel	INR 25 per BOE

Variable storage cost applies to the closing storage volume each week.

Demand Data

Product	Base Weekly Demand
Crude Oil	78,000 barrels per week
Natural Gas	32,000 BOE per week

Weekly demand volatility factors have been provided in the data template. Demand for the week can be derived using the multiplicative adjustments for that week applied to base demand. For example, a factor of 1.02 means demand is 2% higher than the base level.

Pricing and Exchange Rate

Parameter	Base Value
Crude oil price	USD 72 per barrel

Natural gas price	INR 3,200 per BOE
Exchange rate	INR 83 per USD

Excess Capacity Disposal

In any week where BOEL's actual production capacity **for a product** exceeds the volume that can be absorbed by market sales/demand and residual storage, the company cannot simply curtail output without incurring significant well-integrity costs. Accordingly, BOEL has arrangements in place to dispose of any such excess volume through alternative channels at a discount to the prevailing commodity price.

Crude Oil: Any crude oil that cannot be sold at the prevailing export price and cannot be stored (because storage is full) is sold into the domestic spot market at a 70% discount to the prevailing crude oil price. This reflects the limited domestic refining appetite for incremental spot barrels and the logistical cost of rerouting tankers to domestic terminals.

Natural Gas: Any natural gas that cannot be sold at the prevailing pipeline price and cannot be stored is supplied to large industrial consumers (fertiliser plants, petrochemical facilities and power generators) under short-term emergency offtake agreements at a 50% discount to the prevailing gas price. These agreements are activated on a rolling weekly basis, as BOEL's gas is already connected to the national grid and can be directed to nominated industrial consumers with minimal incremental cost.

Excess capacity disposal revenue is included in Total Revenue for the week in which it occurs. No additional production cost or storage cost is incurred on disposed volumes.

Revenue is calculated as sales volume multiplied by commodity price, converted by exchange rate wherever applicable.

Weekly **Production Cost** is fixed at INR 245 Mn in week 1 and inflating thereafter.

Storage Costs applicable as described above for each of the products.

All costs inflate weekly at the inflation rate applicable as per the scenario, compounded weekly.

Gross Profit is calculated as the difference between the total revenue and total costs. The company uses a hurdle rate of 10% per annum for the calculation of present value of the profits.

Scenario Descriptions

Scenario 1 – Base

Stable conditions throughout. Demand is subject only to the weekly volatility factors. Prices and exchange rate remain at base values. Annual inflation is 5%.

Scenario 2 – Stress (Geopolitical Shock)

A geopolitical escalation in the Persian Gulf disrupts shipping lanes through the Strait of Hormuz. Weeks 1–9 are identical to the Base Scenario. The shock has two phases:

Phase 1: Acute Shock (Weeks 10 to 25)

- Crude oil exports are fully blocked. BOEL cannot make primary sales of crude oil. Production continues and unsold output either accumulates in storage or is disposed of at the domestic spot price (70% discount) once storage is full.
- Global crude oil price spikes to USD 108 per barrel.
- Natural gas demand increases by 25% above base level as domestic industry pivots to gas.
- Natural gas price increases to INR 3,800 per BOE.
- Exchange rate depreciates to INR 93 per USD.
- Annual inflation increases to 9%.

Phase 2: New Normal (Weeks 26 to 80)

- Crude oil exports resume but are restricted to 85% of the normal effective demand.
- Crude oil price stabilises at USD 79 per barrel.
- Natural gas demand stabilises at 10% above base level.
- Natural gas price stabilises at INR 3,500 per BOE.
- Exchange rate stabilises at INR 88 per USD.
- Annual inflation: 9% for Weeks 26–45, then 6% for Weeks 46–80.

Additional Guidance

Additional Guidance A: Jarque-Bera Test for Normality

The Jarque-Bera (JB) test checks whether data has skewness and kurtosis consistent with a Normal distribution.

Step 1: Calculate the sample mean (μ) and sample standard deviation (σ) of the demand volatility factors.

Step 2: Calculate sample skewness:

$$s = \left(\frac{1}{n}\right) \times \sum \left(\frac{x_i - \mu}{\sigma}\right)^3$$

Step 3: Calculate sample excess kurtosis:

$$K = \left\{ \left(\frac{1}{n}\right) \times \sum \left(\frac{x_i - \mu}{\sigma}\right)^4 \right\} - 3$$

Step 4: Calculate the JB statistic:

$$JB = \left(\frac{n}{6}\right) \times \left[s^2 + \left(\frac{K^2}{4}\right) \right]$$

Step 5: Compare with the Chi-Squared critical value at 2 degrees of freedom and 95% significance level. If $JB < \text{critical value}$, normality cannot be rejected.

Candidates should also check normality using graphical checks.
