UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2023 SEMESTER

COURSE	**:**	**MEB4323 - ASSET INTEGRITY & RISK MANAGEMENT**
DATE	**:**	**10 APRIL 2023 (MONDAY)**
TIME	**:**	**9.00 AM - 12.00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **TEN (10)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. **FIGURE Q1** shows a pressurized system in a petrochemical plant. Nitrogen liquid is fed from the storage facility into the jacketed process vessel B1 through valve V1. It then goes through the jacketed process vessels, B2 and B3 where various additives are incorporated. The product is cleaned within the catalyst column B4 and stored in vessel B5 and it is ready for despatch via valve V12.

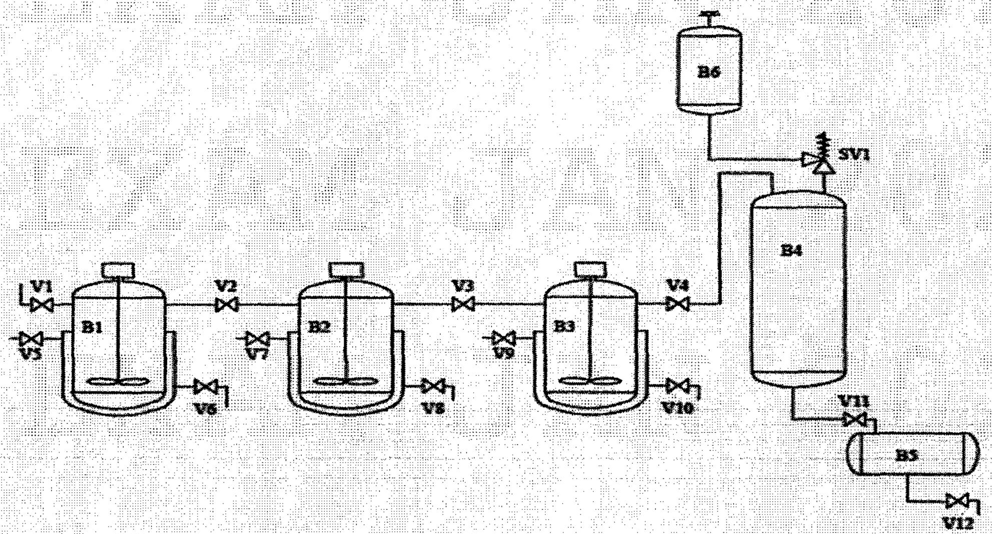

FIGURE Q1

As an inspection engineer, your task is to carry out Risk-based Inspection (RBI) analysis for the system in order to reduce the probability of failure of equipment and the consequences of failure.

a. Develop a flowchart for the steps used in the RBI methodology and identify the critical parameters in each step.

[7 marks]

b. RBI can be classified into **THREE (3)** categories. Differentiate among these categories and highlight the strengths and weaknesses of each category.

[6 marks]

c. **TABLES Q1a** and **Q1b** show the assessment of risk for the critical equipment of the system, namely the jacketed process vessels, B1, B2 and B3. Using the semi-quantitative approach, assess the overall risk rating for the jacketed process vessels (Note: Refer to **APPENDIX** in order to establish the risk ranking based on the 5 × 5 risk matrix).

[12 marks]

TABLE Q1a: The Probability of Failure

Failure Modes	**Vessel B1, B2 and B3: jacketed process vessel**
Internal Corrosion	At the current corrosion rate it is calculated that the remaining life is in excess of 10 years.
Fatigue	The loading by the agitator is very low and well below 20% design life.
Stress Corrosion Cracking	This is not considered significant.

TABLE Q1b: The Consequence of Failure

Consequence of Failure	**Vessel B1, B2 and B3**
Impact of production	The anticipated failure modes are unlikely to occur in a sudden manner and therefore any potential repair can be planned.
Location (Personnel)	The location is only accessible with clearance from control room.
Location - Equipment	The location is relatively dense, and any failure could have an impact on surrounding equipment
Fluid Characteristics	The process fluid is a non-hazardous hydrocarbon
Fluid Hazard (Content)	The process fluid is a notifiable substance, however the quantity is below that prescribed.
Fluid Hazard (Pressure)	The process fluid is at a pressure not exceeding 3 barg.

2. Pressure relief device (PRD) serves to control and limit the pressure by directing the flow into an additional path. Based on the API 581 standard, the PRD has a risk of failure that oil and gas companies need to conduct regular inspections to ensure the reliability of PRDs. One approach to evaluating critically the PRDs for arranging and scheduling programs is to use the risk-based inspection (RBI) method. The probability of failure assessment for PRDs is based on Weibull analysis which is described by its two parameters, the shape parameter β and the characteristic life η.

a. Construct the bathtub curve and assess the various failure rates over the life cycle of the PRDs.

[6 marks]

b. **TABLE Q2** shows the time-to-failure data due to leak for the balanced bellow PRDs operating in severe environment.

i. Assuming the data can fit well into the Weibull distribution, determine its parameters, β and η.

[14 marks]

ii. Estimate the probability of failure of the PRDs after running for 10 years.

[3 marks]

iii. Propose a good maintenance strategy for these PRDs by evaluating its β value.

[2 marks]

TABLE Q2

No.	Time-to-Failure (in year)	No.	Time-to-Failure (in year)
1	27.76	**6**	5.58
2	14.54	**7**	18.65
3	14.09	**8**	7.5
4	7.75	**9**	7.63
5	29.82	**10**	8.01

3. **FIGURE Q3** shows the RTM (Replacement Tire Monitor) which provides the user with a warning when the tyre is worn and has to be replaced. The inscription "Replacement Tire Monitor" shows three times on the circumferential rib of the new tyre. Just before the tread reaches the minimum tread depth indicated by the TWI (Tread Wear Indicator bars), the inscription will change to "Replace Tyre".

FIGURE Q3

To assess the condition of the tire, the tread depths of several tires are measured every 5,000 km. Failure is defined as the time when the depth is less than 2 mm. **TABLE Q3** gives the tire tread degradation measurements.

TABLE Q3

Mileage (km)	Tire A	Tire B	Tire C	Tire D	Tire E
10,000	6.1	5.9	5.9	6.1	6.3
15,000	5.0	5.1	5.0	5.0	5.3
20,000	4.0	4.3	4.05	4.1	4.2
25,000	3.2	3.3	3.5	3.4	3.5
30,000	2.8	2.9	2.9	2.8	2.5
35,000	2.2	2.4	2.4	2.3	2.1

a. Describe the difference between natural degradation and forced degradation.

[4 marks]

b. Conduct the degradation analysis using linear model for tire A and B.

[15 marks]

c. Assess the failure time for each tire. The linear degradation models for tire C, D and E are shown in **TABLE Q3c**. Determine which tire will degrade first.

[6 marks]

TABLE Q3c

Parameters	Tire C	Tire D	Tire E
Slope	-0.139	-0.15	-0.172
Intercept	7.089	7.331	7.853

4. a. Hazard analysis in risk assessment which can be achieved using either fault tree analysis (FTA) or event tree analysis (ETA). Highlight the strengths and weaknesses of ETA.

[6 marks]

b. **FIGURE Q4** shows the event tree analysis (ETA) for natural gas pipeline leakage. The initiating event for the ETA is "Gas release".

i. Determine the probability of each event to occur.

[12 marks]

ii. Determine which event has the highest probability of failure and propose 2 ways to reduce this event.

[7 marks]

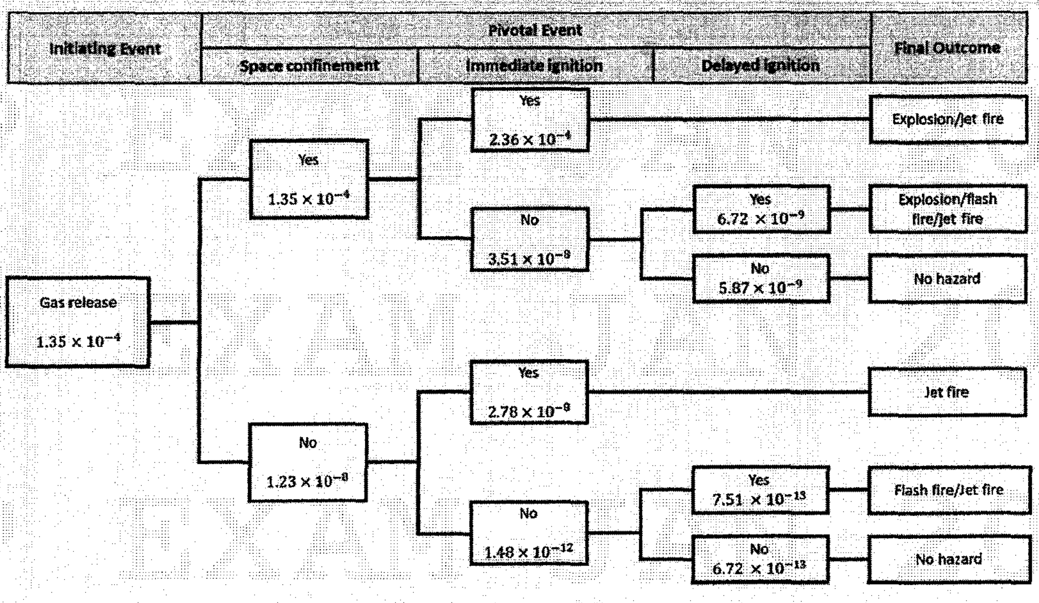

FIGURE Q4

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APPENDIX

Probability of Failure

Internal Corrosion:

Rating	Description
Highly probable	Allowable loss is already used up
Probable	Remaining life 3 - 5 years
Possible	Remaining life 5 – 7 years
Unlikely	Remaining life 7 – 10 years
Very unlikely	Remaining life > 10 years

Fatigue:

Rating	Description
Highly probable	Operating life > 60% Design life
Probable	Operating life < 60% Design life
Possible	Operating life < 40% Design life
Unlikely	Operating life < 20% Design life
Very unlikely	Not considered significant

Stress Corrosion Cracking:

Rating	Description
Highly probable	Experience of wide spread cracking in similar vessels
Probable	Experience of very localised cracking in similar vessels
Possible	Very little experience of cracking in similar vessels
Unlikely	No experience of cracking in similar vessels
Very unlikely	Not considered significant

Consequence of Failure

Impact of production:

Rating	Description
4	Sudden failure possible – Prolonged repair
3	Sudden failure possible – Short repair
2	Predictable failure – Planned repair
1	Standby plant – Little or no impact

Location - Personnel:

Rating	Description
3	Heavily populated
2	Routinely accessible
1	Inaccessible without clearance

Location - Equipment:

Rating	Description
3	Dense installation
2	General installation
1	Remote installation

Fluid Characteristics:

Rating	Description
3	Hazardous
2	Hydrocarbons – neither inert or hazardous
1	Inert/less than 100°C

Fluid Hazard - Contents:

Rating	Description
3	Notifiable substance > prescribed quantity
2	Notifiable substance < prescribed quantity
1	No notifiable substance

Fluid Hazard - Pressure:

Rating	Description
3	> 30 Bar
2	> 7 Bar < 30 Bar
1	< 7 Bar

<u>Consequence Rating:</u>

Rating	Description
Very high	16 – 19
High	13 – 15
Moderate	10 – 12
Low	8 – 10
Very low	6 – 8

Overall Risk Rating:

Overall Risk Rating		Probability of failure				
		Highly probable	Probable	Possible	Unlikely	Very unlikely
Consequence of failure	Very high	Very high	Very high	High	Moderate	Low
	High	Very high	High	Moderate	Low	Low
	Moderate	High	Moderate	Moderate	Low	Very low
	Low	Moderate	Low	Low	Low	Very low
	Very low	Low	Low	Very low	Very low	Very low

Linear Model

Slope:

$$\hat{b} = \frac{\sum_{i=1}^{N} x_i y_i - \frac{\sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N}}{\sum_{i=1}^{N} x_i^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N}}$$

Intercept:

$$\hat{a} = \frac{\sum_{i=1}^{N} y_i}{N} - \hat{b}\frac{\sum_{i=1}^{N} x_i}{N} = \bar{y} - \hat{b}\bar{x}$$

Weibull Distribution (cdf)

$$F(t) = 1 - e^{-\left(\frac{t}{\eta}\right)^{\beta}}$$

$$\ln\left(\ln\left(\frac{1}{1-F(t)}\right)\right) = \beta \ln(t) - \beta \ln(\eta)$$

$$y = \ln\left(\ln\left(\frac{1}{1-F(t)}\right)\right)$$

$$x = \ln(t)$$

$$y = \beta x - \beta \ln(\eta)$$

Median Rank, $r_i = \frac{i - 0.3}{N + 0.4}$