UNIVERSITI TEKNOLOGI PETRONAS

# FINAL EXAMINATION
# JANUARY 2024 SEMESTER

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|---|---|---|
| **COURSE** | **:** | **MEB4333 - ASSET RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)** |
| **DATE** | **:** | **18 APRIL 2024 (THURSDAY)** |
| **TIME** | **:** | **2.30 PM - 5.30 PM (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 **TWELVE (12)** pages in this Question Booklet including the cover page and appendix.

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

1. A study has been conducted to estimate the life distribution of mechanical seals for pumps operated in highly corrosive and abrasive environment. The observation period of one year (8760 hours) for five new seals (for both at the drive end (DE) and non-drive end (NDE)) were performed and the failures for the seals were recorded. All the seals failed at 628, 3444, 822, 846 and 236 hours of operation. It is assumed that the failure data conforms well to the Exponential distribution, having the failure rate of 0.00065 failure/hour.

   a. The analysis must be presented to the management in order to project the number of spares needed in the warehouse. How would you justify that the selected Exponential distribution is the right distribution to represent the life of the seals at 90% confidence level?

   [8 marks]

   b. Estimate the upper and lower bounds for the mean time to failures (MTTF) of the seals at 90% confidence level.

   [8 marks]

   c. Evaluate the probability that the seal will fail within 1000 hours of operation

   [3 marks]

   d. The reliability characteristics of any item throughout its service life can be typically explained in 3 different stages. You are required to illustrate and discuss the 3 stages.

   [6 marks]

2. ChemInd Sdn. Bhd. is a chemical manufacturing plant producing speciality chemical used as detergents for high performance fuel or dispersants for lubricant. Due to past year's high maintenance cost and high breakdown time, the plant's general manager instructed the asset and reliability team to review all the equipment, as well as piping and instrumentation items in order to reduce the maintenance cost and breakdown time.

From the data collected by the asset and reliability team, they noticed that the mechanical seal equipped to five centrifugal pumps failed at 209, 163, 271, 196 and 188 days of operation. The failure data is assumed to fit well in the Weibull distribution.

a. Weibull distribution has two parameters which are $\beta$, the shape parameter and $\eta$, the scale parameter. Prove that $m = \beta$ and $c = -\beta\, ln(\eta)$ by performing the linearization steps of the Weibull cumulative distribution function,

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

so that you will get in term of a linear equation, $y = mx + c$.

[8 marks]

b. Using the median ranking method and the rank regression method in **part (a)**, assess the parameters for Weibull distribution. Comment the $\beta$ value.

[11 marks]

c. Determine the upper and lower 90% confidence limits on the true value of $\beta$ and $\eta$.

[6 marks]

3. A fluid dispensing system consists of a main valve and two pumps arranged in parallel configuration. The main valve is used to control the fluid flow from the two pumps. Both pumps are driven by electric motors. Because of the recent safety incident, you, as a reliability engineer, are tasked to study and to predict the reliability of the fluid dispensing system so that mitigation plans can be put in place to prevent unscheduled breakdown.

The analysis of the system indicates that pump is one of the critical equipment. **TABLE Q3** shows the time between failures data and the end of observation time is at 900 days.

**TABLE Q3**

| No | Time between failures (days) |
|---|---|
| 1 | 150 |
| 2 | 188 |
| 3 | 61 |
| 4 | 105 |
| 5 | 199 |
| 6 | 110 |

a. Apply the Laplace trend test in your analysis and conclude your finding.

[6 marks]

b. Assuming the pump went through minimal repair, estimate the expected number of failures and reliability, three years after the observation ended.

[14 marks]

c. Discuss **THREE (3)** advantages and **TWO (2)** limitations of performing repairable system analysis using reliability block diagram.

[5 marks]

4. There has been a continuing and increasing interest in methods for power system reliability assessment and one of the methods used is fault tree analysis. **FIGURE Q4** shows one of the fault trees developed to estimate the risk for power system configuration.

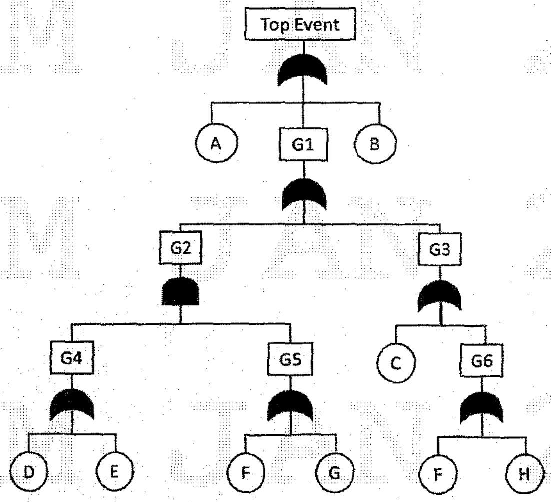


**FIGURE Q4**

a. By using bottom-up approach ONLY, propose the minimal cut set for the fault tree and draw the simplified fault tree.

[12 marks]

b. Then, by using ONLY the simplified fault tree, determine the probability of the top event to occur by employing the probabilities of occurrence of basic events as shown in **TABLE Q4**.

**TABLE Q4**: Probabilities of occurrence of basic events

| **Event** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** |
|---|---|---|---|---|---|---|---|---|
| **Probability** | 0.15 | 0.18 | 0.04 | 0.03 | 0.05 | 0.11 | 0.09 | 0.02 |

[8 marks]

c. Discuss **FIVE (5)** key features of cut set and minimal cut set with regards to fault tree analysis.

[5 marks]

- END OF PAPER -

# FORMULA SHEET

Normal distribution :

Sample standard deviation

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2},$$

Standardized normal variate (Z Table)

$$Z = \frac{X - \mu}{\sigma}$$

Adjust rank

$$i = Adjusted\ Rank = \frac{Reverse\ Rank\ x\ Previous\ adjusted\ Rank + (N+1)}{1 + (Reverse\ Rank)}$$

Median rank (Bernard's approximation):

$$Median\,Rank\,r_j = \frac{j - 0.3}{N + 0.4}$$

j = Failure order number (rank number)

N = sample size

Two-Parameter Weibull:

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

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

Confidence bounds for Weibull Parameters:

$$\hat{\beta}\, exp\left(\frac{-0.78 z_{1-\alpha/2}}{\sqrt{n}}\right) \le \beta \le \hat{\beta}\, exp\left(\frac{0.78 z_{1-\alpha/2}}{\sqrt{n}}\right)$$

$$\hat{\eta}\, exp\left(\frac{-1.05 z_{1-\alpha/2}}{\hat{\beta}\sqrt{n}}\right) \le \eta \le \hat{\eta}\, exp\left(\frac{1.05 z_{1-\alpha/2}}{\hat{\beta}\sqrt{n}}\right)$$

Exponential Distribution

$$f(t) = \lambda e^{-\lambda t} = \frac{1}{m} e^{-\frac{1}{m}t} \qquad F(t) = 1 - e^{-\lambda t} = 1 - e^{-\frac{1}{m}t}$$

Linearizing Exponential:

$$\ln\left[\frac{1}{1-F(t)}\right] = \lambda t$$

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

$$y = Bx + C$$

$\boldsymbol{x: t}$

$\boldsymbol{B: Slope = \lambda}$

Confidence bounds for exponential

$$\text{MTBF}_U = \frac{2\sum_{i=1}^{n} x_i}{\chi^2_{1-\frac{\alpha}{2},k}}$$

$$\text{MTBF}_L = \frac{2\sum_{i=1}^{n} x_i}{\chi^2_{\alpha/2,k}}$$

Where $k = \begin{cases} 2(r+1) & \text{forType}I\text{data} \\ 2r & \text{forTypeII or completedata} \end{cases}$

Lognormal Distribution

$$F(x) = \Phi\left(\frac{\ln x - \mu}{\sigma}\right) \qquad f(t') = \frac{1}{\sigma'\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t'-\mu'}{\sigma'}\right)^2}$$

$$A_A = \frac{MTBMA}{MTBMA + MMT}$$

$$MTBMA = \frac{1}{\lambda + f_{PM}}$$

$\lambda$ = the failure rate (assuming all failures are repaired).
$f_{PM}$ = the frequency of preventive maintenance, the reciprocal of PM Cycle.

$$MMT = \frac{\lambda\, MTTR + f_{PM} MPMT}{\lambda + f_{PM}}$$

Where *MTTR* is the mean CM time and *MPMT* is the mean PM time.

$$L = \frac{\frac{\sum_{j=1}^{\hat{n}} T_j}{\hat{n}} - \frac{1}{2}(b+a)}{\sqrt{\frac{1}{12(\hat{n})}(b-a)^2}}$$

a – start of observation time
b – end of observation time
$T_j$ – cumulative time between failure
$\hat{n}$ – number of failure
Note: If the last failure occurs at the end of the observation period (i.e., $t_n = T$), then use n - 1 instead of n in the formula

$$\hat{\beta} = \frac{r}{r\ln(T) - \sum_{i=1}^{r} \ln(T_i)}$$

$$\hat{\lambda} = \frac{r}{T^{\hat{\beta}}}$$

*r - number of failure*
*T - observation time*

$$E\{N(T_2) - N(T_1)\} = \lambda\left(T_2^{\beta} - T_1^{\beta}\right)$$

$$R(T_1, T_2) = e^{-\lambda\left(T_2^{\beta} - T_1^{\beta}\right)}$$

$$R(t) = e^{-[\lambda(t+d)^{\beta} - \lambda t^{\beta}]}$$

$$\text{MTBF}(T_1, T_2) = \frac{(T_2 - T_1)}{\lambda\left(T_2^{\beta} - T_1^{\beta}\right)}$$

**Rank Regression, *y= bx + a***

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

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

**Correlation coefficient, *r*:**

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\,n\Sigma x^2 - (\Sigma x)^2\,][\,n\Sigma y^2 - (\Sigma y)^2\,]}} = \frac{\sum_{i=1}^{N} x_i y_i - \frac{\sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N}}{\sqrt{\left(\sum_{i=1}^{N} x_i^2 - \frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N}\right)\left(\sum_{i=1}^{N} y_i^2 - \frac{\left(\sum_{i=1}^{N} y_i\right)^2}{N}\right)}}$$

**Coefficient of determination = $r^2$**

**Boolean Algebra rules**

| Rules | Expressions |
|---|---|
| **1. Associative Law** | **(A + B) + C = A + (B + C) = A + B + C**<br>**(AB)C = A(BC) = ABC** |
| **2. Distributive Law** | **X (Y + Z) = XY + XZ**<br>**X + YZ = (X + Y)(X + Z)** |
| **3. Commutative Law** | **AB = BA**<br>**A + B = B + A** |
| **4. Absorption Law** | **X + XY = X**<br>**X (X + Y) = X** |
| **5. Idempotent Law** | **A•A = A**<br>**A + A = A** |

## Standard Normal Table, Z

| x | 0 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.5000 | 0.5040 | 0.5080 | 0.5120 | 0.5160 | 0.5199 | 0.5239 | 0.5279 | 0.5319 | 0.5359 |
| 0.1 | 0.5398 | 0.5438 | 0.5478 | 0.5517 | 0.5557 | 0.5596 | 0.5636 | 0.5675 | 0.5714 | 0.5753 |
| 0.2 | 0.5793 | 0.5832 | 0.5871 | 0.5910 | 0.5948 | 0.5987 | 0.6026 | 0.6064 | 0.6103 | 0.6141 |
| 0.3 | 0.6179 | 0.6217 | 0.6255 | 0.6293 | 0.6331 | 0.6368 | 0.6406 | 0.6443 | 0.6480 | 0.6517 |
| 0.4 | 0.6554 | 0.6591 | 0.6628 | 0.6664 | 0.6700 | 0.6736 | 0.6772 | 0.6808 | 0.6844 | 0.6879 |
| 0.5 | 0.6915 | 0.6950 | 0.6985 | 0.7019 | 0.7054 | 0.7088 | 0.7123 | 0.7157 | 0.7190 | 0.7224 |
| 0.6 | 0.7257 | 0.7291 | 0.7324 | 0.7357 | 0.7389 | 0.7422 | 0.7454 | 0.7486 | 0.7517 | 0.7549 |
| 0.7 | 0.7580 | 0.7611 | 0.7642 | 0.7673 | 0.7704 | 0.7734 | 0.7764 | 0.7794 | 0.7823 | 0.7852 |
| 0.8 | 0.7881 | 0.7910 | 0.7939 | 0.7967 | 0.7995 | 0.8023 | 0.8051 | 0.8078 | 0.8106 | 0.8133 |
| 0.9 | 0.8159 | 0.8186 | 0.8212 | 0.8238 | 0.8264 | 0.8289 | 0.8315 | 0.8340 | 0.8365 | 0.8389 |
| 1.0 | 0.8413 | 0.8438 | 0.8461 | 0.8485 | 0.8508 | 0.8531 | 0.8554 | 0.8577 | 0.8599 | 0.8621 |
| 1.1 | 0.8643 | 0.8665 | 0.8686 | 0.8708 | 0.8729 | 0.8749 | 0.8770 | 0.8790 | 0.8810 | 0.8830 |
| 1.2 | 0.8849 | 0.8869 | 0.8888 | 0.8907 | 0.8925 | 0.8944 | 0.8962 | 0.8980 | 0.8997 | 0.9015 |
| 1.3 | 0.9032 | 0.9049 | 0.9066 | 0.9082 | 0.9099 | 0.9115 | 0.9131 | 0.9147 | 0.9162 | 0.9177 |
| 1.4 | 0.9192 | 0.9207 | 0.9222 | 0.9236 | 0.9251 | 0.9265 | 0.9279 | 0.9292 | 0.9306 | 0.9319 |
| 1.5 | 0.9332 | 0.9345 | 0.9357 | 0.9370 | 0.9382 | 0.9394 | 0.9406 | 0.9418 | 0.9429 | 0.9441 |
| 1.6 | 0.9452 | 0.9463 | 0.9474 | 0.9484 | 0.9495 | 0.9505 | 0.9515 | 0.9525 | 0.9535 | 0.9545 |
| 1.7 | 0.9554 | 0.9564 | 0.9573 | 0.9582 | 0.9591 | 0.9599 | 0.9608 | 0.9616 | 0.9625 | 0.9633 |
| 1.8 | 0.9641 | 0.9649 | 0.9656 | 0.9664 | 0.9671 | 0.9678 | 0.9686 | 0.9693 | 0.9699 | 0.9706 |
| 1.9 | 0.9713 | 0.9719 | 0.9726 | 0.9732 | 0.9738 | 0.9744 | 0.9750 | 0.9756 | 0.9761 | 0.9767 |
| 2.0 | 0.9772 | 0.9778 | 0.9783 | 0.9788 | 0.9793 | 0.9798 | 0.9803 | 0.9808 | 0.9812 | 0.9817 |
| 2.1 | 0.9821 | 0.9826 | 0.9830 | 0.9834 | 0.9838 | 0.9842 | 0.9846 | 0.9850 | 0.9854 | 0.9857 |
| 2.2 | 0.9861 | 0.9864 | 0.9868 | 0.9871 | 0.9875 | 0.9878 | 0.9881 | 0.9884 | 0.9887 | 0.9890 |
| 2.3 | 0.9893 | 0.9896 | 0.9898 | 0.9901 | 0.9904 | 0.9906 | 0.9909 | 0.9911 | 0.9913 | 0.9916 |
| 2.4 | 0.9918 | 0.9920 | 0.9922 | 0.9925 | 0.9927 | 0.9929 | 0.9931 | 0.9932 | 0.9934 | 0.9936 |
| 2.5 | 0.9938 | 0.9940 | 0.9941 | 0.9943 | 0.9945 | 0.9946 | 0.9948 | 0.9949 | 0.9951 | 0.9952 |
| 2.6 | 0.9953 | 0.9955 | 0.9956 | 0.9957 | 0.9959 | 0.9960 | 0.9961 | 0.9962 | 0.9963 | 0.9964 |
| 2.7 | 0.9965 | 0.9966 | 0.9967 | 0.9968 | 0.9969 | 0.9970 | 0.9971 | 0.9972 | 0.9973 | 0.9974 |
| 2.8 | 0.9974 | 0.9975 | 0.9976 | 0.9977 | 0.9977 | 0.9978 | 0.9979 | 0.9979 | 0.9980 | 0.9981 |
| 2.9 | 0.9981 | 0.9982 | 0.9982 | 0.9983 | 0.9984 | 0.9984 | 0.9985 | 0.9985 | 0.9986 | 0.9986 |
| 3.0 | 0.9987 | 0.9987 | 0.9987 | 0.9988 | 0.9988 | 0.9989 | 0.9989 | 0.9989 | 0.9990 | 0.9990 |
| 3.1 | 0.9990 | 0.9991 | 0.9991 | 0.9991 | 0.9992 | 0.9992 | 0.9992 | 0.9992 | 0.9993 | 0.9993 |
| 3.2 | 0.9993 | 0.9993 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9995 | 0.9995 | 0.9995 |
| 3.3 | 0.9995 | 0.9995 | 0.9995 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9997 |
| 3.4 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9998 |

# Kolmogorov-Smirnov Table

| SAMPLE SIZE (N) | LEVEL OF SIGNIFICANCE FOR D = MAXIMUM ABS[ $F_0(X)$ - F(X) ] | | | | |
|---|---|---|---|---|---|
| | 0.20 | 0.15 | 0.10 | 0.05 | 0.01 |
| 1 | 0.900 | 0.925 | 0.950 | 0.975 | 1 |
| 2 | 0.684 | 0.726 | 0.776 | 0.842 | 0.93 |
| 3 | 0.565 | 0.597 | 0.642 | 0.708 | 0.83 |
| 4 | 0.494 | 0.525 | 0.564 | 0.624 | 0.73 |
| 5 | 0.446 | 0.474 | 0.510 | 0.565 | 0.67 |
| 6 | 0.410 | 0.436 | 0.470 | 0.521 | 0.62 |
| 7 | 0.381 | 0.405 | 0.438 | 0.486 | 0.58 |
| 8 | 0.358 | 0.381 | 0.411 | 0.457 | 0.54 |
| 9 | 0.339 | 0.360 | 0.388 | 0.432 | 0.51 |
| 10 | 0.322 | 0.342 | 0.368 | 0.410 | 0.49 |
| 11 | 0.307 | 0.326 | 0.352 | 0.391 | 0.47 |
| 12 | 0.295 | 0.313 | 0.338 | 0.375 | 0.45 |
| 13 | 0.284 | 0.302 | 0.325 | 0.361 | 0.43 |
| 14 | 0.274 | 0.292 | 0.314 | 0.349 | 0.42 |
| 15 | 0.266 | 0.283 | 0.304 | 0.338 | 0.40 |
| 16 | 0.258 | 0.274 | 0.295 | 0.328 | 0.39 |
| 17 | 0.250 | 0.266 | 0.286 | 0.318 | 0.38 |
| 18 | 0.244 | 0.259 | 0.278 | 0.309 | 0.37 |
| 19 | 0.237 | 0.252 | 0.272 | 0.301 | 0.36 |
| 20 | 0.231 | 0.246 | 0.264 | 0.294 | 0.36 |
| 25 | 0.210 | 0.220 | 0.240 | 0.270 | 0.32 |
| 30 | 0.190 | 0.200 | 0.220 | 0.240 | 0.29 |
| 35 | 0.180 | 0.190 | 0.210 | 0.230 | 0.27 |

Chi-Square Table

| DF | Chi-Square Right-Tail Probability ($\geq \chi^2$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| DF | 0.995 | 0.99 | 0.975 | 0.95 | 0.9 | 0.1 | 0.05 | 0.025 | 0.01 | 0.005 |
| 1 | --- | --- | 0.001 | 0.004 | 0.016 | 2.706 | 3.841 | 5.024 | 6.635 | 7.879 |
| 2 | 0.010 | 0.020 | 0.051 | 0.103 | 0.211 | 4.605 | 5.991 | 7.378 | 9.210 | 10.597 |
| 3 | 0.072 | 0.115 | 0.216 | 0.352 | 0.584 | 6.251 | 7.815 | 9.348 | 11.345 | 12.838 |
| 4 | 0.207 | 0.297 | 0.484 | 0.711 | 1.064 | 7.779 | 9.488 | 11.143 | 13.277 | 14.860 |
| 5 | 0.412 | 0.554 | 0.831 | 1.145 | 1.610 | 9.236 | 11.070 | 12.833 | 15.086 | 16.750 |
| 6 | 0.676 | 0.872 | 1.237 | 1.635 | 2.204 | 10.645 | 12.592 | 14.449 | 16.812 | 18.548 |
| 7 | 0.989 | 1.239 | 1.690 | 2.167 | 2.833 | 12.017 | 14.067 | 16.013 | 18.475 | 20.278 |
| 8 | 1.344 | 1.646 | 2.180 | 2.733 | 3.490 | 13.362 | 15.507 | 17.535 | 20.090 | 21.955 |
| 9 | 1.735 | 2.088 | 2.700 | 3.325 | 4.168 | 14.684 | 16.919 | 19.023 | 21.666 | 23.589 |
| 10 | 2.156 | 2.558 | 3.247 | 3.940 | 4.865 | 15.987 | 18.307 | 20.483 | 23.209 | 25.188 |
| 11 | 2.603 | 3.053 | 3.816 | 4.575 | 5.578 | 17.275 | 19.675 | 21.920 | 24.725 | 26.757 |
| 12 | 3.074 | 3.571 | 4.404 | 5.226 | 6.304 | 18.549 | 21.026 | 23.337 | 26.217 | 28.300 |
| 13 | 3.565 | 4.107 | 5.009 | 5.892 | 7.042 | 19.812 | 22.362 | 24.736 | 27.688 | 29.819 |
| 14 | 4.075 | 4.660 | 5.629 | 6.571 | 7.790 | 21.064 | 23.685 | 26.119 | 29.141 | 31.319 |
| 15 | 4.601 | 5.229 | 6.262 | 7.261 | 8.547 | 22.307 | 24.996 | 27.488 | 30.578 | 32.801 |
| 16 | 5.142 | 5.812 | 6.908 | 7.962 | 9.312 | 23.542 | 26.296 | 28.845 | 32.000 | 34.267 |
| 17 | 5.697 | 6.408 | 7.564 | 8.672 | 10.085 | 24.769 | 27.587 | 30.191 | 33.409 | 35.718 |
| 18 | 6.265 | 7.015 | 8.231 | 9.390 | 10.865 | 25.989 | 28.869 | 31.526 | 34.805 | 37.156 |
| 19 | 6.844 | 7.633 | 8.907 | 10.117 | 11.651 | 27.204 | 30.144 | 32.852 | 36.191 | 38.582 |
| 20 | 7.434 | 8.260 | 9.591 | 10.851 | 12.443 | 28.412 | 31.410 | 34.170 | 37.566 | 39.997 |
| 21 | 8.034 | 8.897 | 10.283 | 11.591 | 13.240 | 29.615 | 32.671 | 35.479 | 38.932 | 41.401 |
| 22 | 8.643 | 9.542 | 10.982 | 12.338 | 14.041 | 30.813 | 33.924 | 36.781 | 40.289 | 42.796 |
| 23 | 9.260 | 10.196 | 11.689 | 13.091 | 14.848 | 32.007 | 35.172 | 38.076 | 41.638 | 44.181 |
| 24 | 9.886 | 10.856 | 12.401 | 13.848 | 15.659 | 33.196 | 36.415 | 39.364 | 42.980 | 45.559 |
| 25 | 10.520 | 11.524 | 13.120 | 14.611 | 16.473 | 34.382 | 37.652 | 40.646 | 44.314 | 46.928 |
| 26 | 11.160 | 12.198 | 13.844 | 15.379 | 17.292 | 35.563 | 38.885 | 41.923 | 45.642 | 48.290 |
| 27 | 11.808 | 12.879 | 14.573 | 16.151 | 18.114 | 36.741 | 40.113 | 43.195 | 46.963 | 49.645 |
| 28 | 12.461 | 13.565 | 15.308 | 16.928 | 18.939 | 37.916 | 41.337 | 44.461 | 48.278 | 50.993 |
| 29 | 13.121 | 14.256 | 16.047 | 17.708 | 19.768 | 39.087 | 42.557 | 45.722 | 49.588 | 52.336 |
| 30 | 13.787 | 14.953 | 16.791 | 18.493 | 20.599 | 40.256 | 43.773 | 46.979 | 50.892 | 53.672 |
| 40 | 20.707 | 22.164 | 24.433 | 26.509 | 29.051 | 51.805 | 55.758 | 59.342 | 63.691 | 66.766 |
| 50 | 27.991 | 29.707 | 32.357 | 34.764 | 37.689 | 63.167 | 67.505 | 71.420 | 76.154 | 79.490 |
| 60 | 35.534 | 37.485 | 40.482 | 43.188 | 46.459 | 74.397 | 79.082 | 83.298 | 88.379 | 91.952 |
| 70 | 43.275 | 45.442 | 48.758 | 51.739 | 55.329 | 85.527 | 90.531 | 95.023 | 100.425 | 104.215 |
| 80 | 51.172 | 53.540 | 57.153 | 60.391 | 64.278 | 96.578 | 101.879 | 106.629 | 112.329 | 116.321 |
| 90 | 59.196 | 61.754 | 65.647 | 69.126 | 73.291 | 107.565 | 113.145 | 118.136 | 124.116 | 128.299 |
| 100 | 67.328 | 70.065 | 74.222 | 77.929 | 82.358 | 118.498 | 124.342 | 129.561 | 135.807 | 140.169 |