<u>Self Assessment Questions (SAQs) 1</u>

- Can you define reliability?

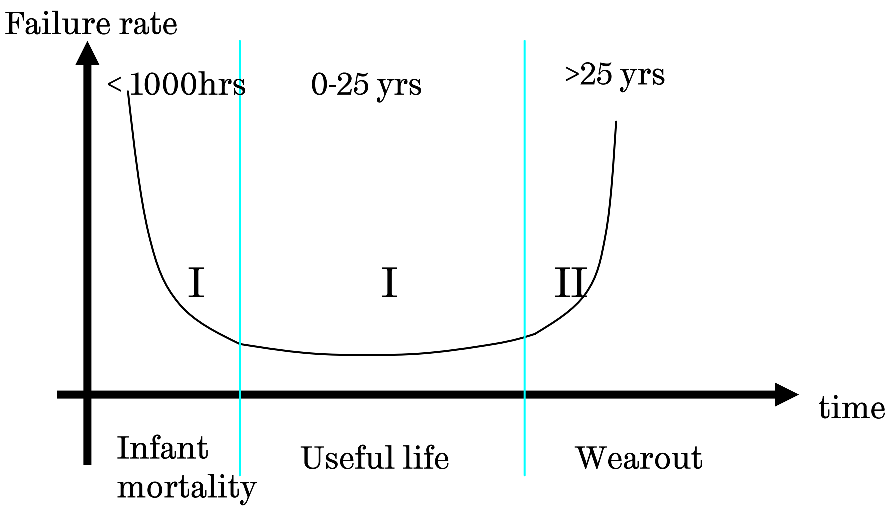
Reliability can be defined as the **probability** of a system or a product **performing** its intended function over a **stated period of time** under a **specified conditions**.

- What is the difference between reliability and quality?

Quality can be defined as optimization of performance. It is not time dependent. Quality of a product is considered as acceptable once the product passes a series of tests. On the other hand reliability is related to the probability of the product performing its function according to its specifications over a stated period of time.

- Can you describe the characteristics of bathtub curve and provide the failure reasons?

Bathtub curve can be divided into three distinct sections as shown below.



(I) The failure rate decreases rapidly with time. Failure rate is usually dominated by defects such as growth defects, processing faults and design faults. This is usually modelled using the Weibull distribution.
(II) The failure rate is constant. Failure is random due to unavoidable excessive loads such as transient current overload and ESD. This is normally modelled using the exponential distribution
(III) The failure rate increases rapidly with time. Wearout is due to material or product fatigue leading to deterioration of product characteristics. Electromigration and hot carrier effects are examples of mechanisms that can result in wearout failures. This generally has a normal distribution.

- Are you able to give examples of different failure modes?

  There are many examples in each of the failure modes in the bathtub curve.
  (I) Early life dielectric breakdown due to wrong thickness or wrong deposition conditions.
  (II) Random failure of IC due to ESD
  (III) Failure of filament bulb after long operating hours.

- Can you comment on whether Moore's law is sustainable? Provide arguments for your comments.

Moore's Law is unlikely to be sustainable because of the increase in the transistor density will
(I) increase the cost of fabrication since better lithography techniques are required and tighter control of contaminant is required (purer etchants and solvents).
(II) require improved heat dissipation, better heatsinks and thermal management.
(III) require new technologies and knowledge, for example nanostructure devices may be required, new growth and fabrication technologies are also needed.

- Do you understand the origin of intrinsic and point defects?

<u>Intrinsic point defects</u>
Vacancy: missing atom at the lattice site
Interstitial: an atom residing a non-lattice site
Antisite: an anion or cation appearing on the wrong lattice site in compound semiconductors
<u>Extrinsic point defects</u>
Point defects involving foreign atoms.
Can be substitutional or interstitial if the impurity/foreign atom occupies the lattice site or the interstitial site.
Can originate from oxygen, carbon, metals and dopants.

- Are there any other types of defects?

Defects due to impurity, dislocation, grain boundaries, stacking faults, lattice mismatch etc.. (See lecture notes)

- How can the defects be minimised?

Defects can be minimised by optimising the growth parameters and the fabrication processed.

- Are defects important in device failure? Elaborate your answer.

Material defects are not important is Si devices because of high quality of Si crystal and very mature fabrication technology. However they are important in compound semiconductors where different elements from the periodic table are used to form compounds such as AlGaAs, InAsSb, InGaAsP etc….
In compound semiconductors the quality of the substrate is not as high as Si substrate. Therefore the grown crystal is not as high purity as Si. In addition the lack high quality of natural dielectric and less mature fabrication technology

present further challenges to minimise defect related failure in compound semiconductor devices.

- Do you know how to obtain the cummulative distribution function (CDF) and the probability distribution function (PDF) from a given set of data?

Refer to the example given in lecture.

- Can you calculate the survival probability, the mean time to failure, the standard deviation and the failure rate if the CDF is known?

Refer to lecture notes for the formulas required.

- Do you know how to calculate failure rates of components using the MIL-HDBK-217F?

Look at the example given for an exponential rate.

- Are they advantages and disadvantages of using MIL-HDBK-217F?

Advantages:
Low implementation cost, ~1% of hardware.
Covers many major electronic device categories.
Used successfully in thousands of DoD developments.
Readily available to designers.
Military quality.
Disadvantages:
Outdated, last review in 1991.
Conservative prediction, pessimistic.
Limited recognition from Telco industry.

- Do you know how to analyse failure rate using exponential, lognormal and weibull distributions?

One of the most frequently used techniques in failure analysis is to use some form linear plot of the number of failures as a function of time.
For example by taking successive logs for Weibull distribution we have

$$F(t) = 1 - \exp\left[-\left(t/\alpha\right)^{\beta}\right]$$

$$\ln[1 - F(t)] = -\left(t/\alpha\right)^{\beta} \quad .$$

$$\ln\{-\ln[1 - F(t)]\} = \beta\ln(t) - \beta\ln(\alpha)$$

Comparing to a linear straight line $y = mx + c$ we have

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

$$m = \beta$$

$$x = \ln(t) \quad .$$

$$c = -\beta\ln(\alpha)$$

For lognormal distribution we have

$$F(t) = \Phi\left[\sigma^{-1}\ln\left(\frac{t}{\mu}\right)\right] \quad .$$

$$\Phi^{-1}\sigma F(t) = \ln(t) - \ln(\mu)$$

Here we have a straight line if we plot ln(t) versus $\Phi^{-1}F(t)$.

Special Weibull and lognormal probability papers are available for failure analysis (example: see p.199-201 in Ohring).