CANDIDATE GUIDE

EXERCISE SOUND JUDGMENT IN THE COURSE OF COMPLEX ENGINEERING ACTIVITIES

OUTCOME 9

TABLE OF CONTENTS PAGE NO.

CANDIDATE INFORMATION

Details	Please Complete details
Name of candidate	
Name of supervisor	
Work Unit	
Name of mentor	
Date started	
Date of completion & Assessment	

COMPETENCY STANDARD REQUIREMENTS

(Direct extract from SAIMechE's Standard of Professional Competency)

LEARNING OUTCOME 9

Exercise sound judgement in the course of complex engineering activities.

Assessment Criteria:

A candidate typically exhibits judgment by:

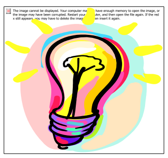
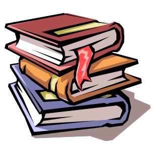
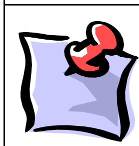
1. Considering several factors, some of which may not be well defined or unknown
2. Considering the interdependence, interactions, and relative importance of factors
3. Foreseeing consequences of actions
4. Evaluating a situation in the absence of full evidence
5. Drawing on experience and knowledge
6. Justifying judgments on risk associated with decisions

Range Statement:

Situations in which judgement must be applied involve interactions between wide-ranging or conflicting technical, engineering or other issues.

KEYS TO ICONS

The following icons are used throughout the study guide to indicate specific functions:

	**DON'T FORGET/NOTE** **This icon indicates information of particular importance**
	**CANDIDATE GUIDE** **This refers to the learning material in this module which is aligned to the SAIMechE Competency Standard**
	**EXERCISES** **Practical activities to do, either individual or in syndicate groups during the training process**
	**BOOKS AND WEBSITES** **Additional resource information for further reading and reference**
	**SELF TEST QUESTIONS** **Self-evaluation for candidates to test understanding of the learning material**
	**QUOTATIONS** **Quotations which offer interesting points of view and statements of wisdom and insight**
	**YOUR NOTE PAD** **Provided for candidate to document notes during presentation of training**

GENERAL GUIDELINES

PURPOSE

This module provides easy-to-follow steps to help you to exercise sound judgement in the course of complex engineering activities. These follow the items listed in section 2 above.

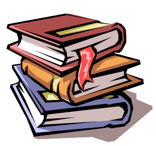
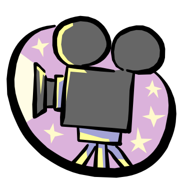
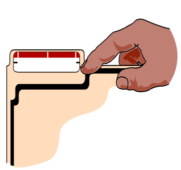
The purpose of the module is to introduce to the Engineer a practical methodology of meeting the requirements of the assessment criteria so as to illustrate compliance with Outcome 9.

The approach to this module is by no means restricted to these guidelines only, and the Candidate is expected to research any appropriate references, literature and practices that can support the essence of this competency outcome.

LEARNING OUTCOME AND RANGE OF LEARNING

This programme uses the basic structure of SAIMechE's Competency Standard, and specifically the assessment criteria, to take you through the process of learning, as an understanding of the assessment criteria and the range of understanding required is fundamental to professional competence.

CANDIDATE SUPPORT

Resources	Candidate Guide 	The Candidate Guide is a manual covering the theory on the comprehension and development of advanced knowledge, and provides the guidance on practical exercises to meet the requirements of the assessment criteria
	Candidate Portfolio of Evidence Guide	This is a separate document which provides guidelines for Candidates on how to compile their portfolio of evidence, and a template to structure their practical task evidence into a file format for assessment by the mentor/referee
	Books and websites 	Refer to references at the end of the Candidate Guide
	Videos 	Refers to any videos that are regarded as relevant to the subject
	Folder enclosures 	This includes all handouts, checklists, etc. as well as “The Engineer’s Code of Conduct”

SECTION 1

EXERCISE SOUND JUDGMENT IN THE COURSE OF COMPLEX ENGINEERING ACTIVITIES

LEARNING OUTCOMES:

- Understand the concept of exercising sound judgment in the course of complex engineering activities

1.0. EXERCISE SOUND JUDGMENT IN THE COURSE OF COMPLEX ENGINEERING ACTIVITIES

1.1. Exercising judgment

We can define exercising sound judgment as the ability to weigh the evidence and come up with the right answer. This sounds reasonable for those instances where the “right answer” is either agreed or apparent. Training people to do this starts with the normal process of teaching by explaining the nature of the subject, its basics, applications, and then progressively expanding into the more complex areas of the subject.

The testing of the students’ grasp on the subject is done by examination: setting questions and having the student exercise judgment with the intention of reaching the right answer. This is the typical educational process where the answers for the examination are known and hence the Candidate’s ability to arrive at the right answer can be tested. What is this process actually doing? It is training the student to apply logical processes and to exercise judgment on the process being used as well as the correctness of the answer. The benchmark is set by the correct answer. Exercising judgment is thus practiced repeatedly until the student and subsequently the Candidate and Engineer can utilise knowledge and experience to solve problems.

Judgment will apply to both the methodology that the Engineer uses as well as to the evidence that is produced. The answer is correct if the solution as judged by the Candidate or the Engineer meets the intended outcome.

1.2. Analysis and Synthesis

The terms “analysis” and “synthesis” come from classical Greek and mean literally "to loosen up" and "to put together" respectively. These terms are used within most modern scientific disciplines - from mathematics and logic to economics and psychology - to denote similar investigative procedures. In general, analysis is defined as the procedure by which we break down an intellectual or substantial whole into parts or components. Synthesis is defined as the opposite procedure: combining separate elements or components in order to form a coherent whole.

There are various analytical methods available to the Engineer in addressing problem-solving. Some of these are listed below and the candidate is encouraged to do independent research into the subject.

For analysis to begin properly, the problem must be carefully stated. The statement, “A problem clearly stated is a problem half solved” has been proven often enough to be regarded as a rule. Sometimes it is stated differently: “If you want the right answer ask the right question”. If this is not done properly, it could lead to one of the following: excessive time in cause identification due to a broad problem statement, predisposing the individual or the team to a particular solution; or problem-solving turns into solution implementation rather than root-cause identification and remedy. This activity then should be the first item on which the Candidate passes judgment.

High performance work teams typically use five problem-solving tools:

1. Plan, Do, Check, Act (PDCA)
2. 5-Why Analysis
3. Ishakawa (Fishbone) Diagram
4. Failure Modes and Effects Analysis (FMEA)
5. Kaizen

These and other tools will be referred to during the programme in various exercises and case studies. The candidate is encouraged to do research on them, and to practise using them in the workplace.

1.3. The Risks of Incomplete Data, Information and Knowledge

It is necessary to distinguish between these three terms which are regularly used incorrectly.

Data:

- Data represents unorganized and unprocessed facts
- Data is usually static in nature
- It can represent a set of discrete facts about events
- Data is a prerequisite to information
- An organization sometimes has to decide on the nature and volume of data that is required for creating the necessary information

Information:

- Information can be considered as an aggregation of data (processed data) which makes decision-making easier
- Information usually has some meaning and purpose

Knowledge:

- By knowledge, we mean human understanding of subject matter that has been acquired through proper study and experience
- Knowledge is usually based on learning, thinking, and proper understanding of the problem area

- Knowledge is derived from information in the same way information is derived from data
- We can view it as an understanding of information based on its perceived importance or relevance to a problem area
- It can be considered as the integration of human perceptive processes that helps us to draw meaningful conclusions

Clearly then, when we start with the process of collecting evidence for purposes of solving complex engineering problems, we need to start with data. This should be done by formally recording all observed, heard or sensed evidence. It is normally wise practice to record more items than may seem to be relevant, as it will only become evident which of the data items are useful when the process of combining data to create information follows. Surplus data can easily be discarded or merely left on record in case it becomes relevant later on. We have all watched detective movies or read crime novels where detectives solve the crime by astute observations. In reality, that is the way it happens, only the movie plot dresses the process in deliberate diversions to keep the plot interesting. One should treat any collection of data as though one is a detective especially as today we have the benefits of forensic analysis, or in our engineering world, the applications of modern NDT and machine health-monitoring systems.

1.4. Risk and Safety Factors

The fundamental reasons why we introduce the concept of safety factors into our lives are actually very obvious, but they are all too often misunderstood or not expressed clearly. Essentially, they are necessary due to the ubiquitous realities of both variability and uncertainty. These two factors are dependent on the nature of the use and application of the device or system under consideration. In life, we experience the practice of “buffering” a process. This, for example, can be shown in the creation of a stockpile in the process of producing a product. The capacity of the buffer smooths the flow, drawing on the surplus capacity to make up reduction in input flow, or absorbing the oversupply to prevent overflow and disruption elsewhere due to blockage. In reality, that is a safety factor at work protecting and stabilising the flow. This facility adds to the initial cost of the system. Similarly, adding to the thickness of a section of material in a structure is providing a “buffer” against overload, ensuring that the stress of the material remains within the its yield or fracture limits. This also adds cost. But when analysed over the life cycle of the system, the cost of providing the surplus capacity at the start will often reduce the cost over the lifecycle, when consideration is given to the cost of failure of the device or system during operation.

It can thus be appreciated that adding safety factors depends on the envisaged performance required of the device or system where it is subjected to known and controlled circumstances, but can also be subjected to credible excursions. Similarly, the material of the device or system may not be entirely predictable, and subject to variability and uncertainty. Safety factors and risk levels are then derived taking into account both intrinsic and extrinsic circumstances. Over time, designs typically have been assigned recommended safety factors that have been determined from experiences during the operating life of such designs. Many of these are incorporated into codes.

1.5. Assumptions and Inferences

We recommend that the Candidate review this extract carefully as it identifies the critical differences between assumptions and inferences. These have a major bearing on the assembly of evidence in making judgment.

To be skilled in critical thinking is to be able to take one’s thinking apart systematically, to analyse each part, assess it for quality and then improve it. The first step in this process is understanding the parts of thinking, or elements of reasoning.

These elements are: purpose, question, information, inference, assumption, point of view, concepts, and implications. They are present in the mind whenever we reason. To take command of our thinking, we need to formulate both our purpose and the question at issue clearly. We need to use information in our thinking that is relevant to the question with which we are dealing. We need to make logical inferences based on sound assumptions. We need to understand our own point of view and fully consider other relevant viewpoints. We need to use concepts justifiably and consider carefully the implications of decisions we are considering. For an elaboration of the Elements of Reasoning, see a Miniature Guide to the Foundations of Analytic Thinking in the References section.

Below is an extract from Critical Thinking: Tools for taking charge of your learning and your life, by Richard Paul and Linda Elder.

In this article we focus on two of the elements of reasoning: inferences and assumptions. Learning to distinguish inferences from assumptions is an important intellectual skill. Many confuse the two elements. Let us begin with a review of the basic meanings:

1. Inference: An inference is a step of the mind, an intellectual act by which one concludes that something is true in light of something else being true, or seeming to be true. If you come at me with a knife in your hand, I probably would infer that you mean to do me harm. Inferences can be accurate or inaccurate, logical or illogical, justified or unjustified. It is unlikely that, if your intention was to get my opinion on its sharpness for some other purpose, I would have inferred that.

2. Assumption: An assumption is something we take for granted or presuppose. Usually it is something we previously learned and do not question. It is part of our system of beliefs. We assume our beliefs to be true and use them to interpret the world about us. If we believe that it is dangerous to walk late at night in big cities and we are staying in Chicago for example, we will assume that it is dangerous to go for a walk late

at night. We take for granted our belief that it is dangerous to walk late at night in big cities. If our belief is a sound one, our assumption is sound. If our belief is not sound, our assumption is not sound. Beliefs, and hence assumptions, can be unjustified or justified, depending upon whether we do or do not have good reasons for them. Consider this example: “I heard a scratch at the door. I got up to let the cat in.” My inference was based on the assumption (my prior belief) that only the cat makes that noise, and that he makes it only when he wants to be let in.

We humans naturally and regularly use our beliefs as assumptions and make inferences based on those assumptions. We must do so to make sense of where we are, what we are about, and what is happening. Assumptions and inferences permeate our lives precisely because we cannot act without them. We make judgments, form interpretations, and come to conclusions based on the beliefs we have formed.

If you put humans in any situation, they start to give it some meaning or other. People automatically make inferences to gain a basis for understanding and action. So quickly and automatically do we make inferences that we do not, without training, notice them as inferences. We see dark clouds and infer rain. We hear the door slam and infer that someone has arrived. We see a frowning face and infer that the person is upset. If our friend is late, we infer that she is being inconsiderate. We meet a tall guy and infer that he is good at basketball, an Asian and infer that she will be good at mathematics. We read a book, and interpret what the various sentences and paragraphs - indeed what the whole book - is saying. We listen to what people say and make a series of inferences as to what they mean.

As we write, we make inferences as to what readers will make of what we are writing. We make inferences as to the clarity of what we are saying, what requires further explanation, what has to be exemplified or illustrated, and what does not. Many of our inferences are justified and reasonable, but some are not.

As always, an important part of critical thinking is the art of bringing what is subconscious in our thought to the level of conscious realization. This includes the recognition that our experiences are shaped by the inferences we make during those experiences. It enables us to separate our experiences into two categories: the raw data of our experience in contrast with our interpretations of those data, or the inferences we are making about them. Eventually we need to realize that the inferences we make are heavily influenced by our point of view and the assumptions we have made about people and situations. This puts us in the position of being able to broaden the scope of our outlook, to see situations from more than one point of view, and hence to become more open-minded.

Often different people make different inferences because they bring to situations different viewpoints. They see the data differently. To put it another way, they make different assumptions about what they see. For example, if two people see a man lying in a gutter, one might infer, “There’s a drunken bum.” The other might infer, “There’s a man in need of help.” These inferences are based on different assumptions about the conditions under which people end up in gutters. Moreover, these assumptions are connected to each person’s viewpoint about people. The first person assumes, “Only drunks are to be found in gutters.” The second person assumes, “People lying in the gutter are in need of help.”

The first person may have developed the point of view that people are fundamentally responsible for what happens to them and ought to be able to care for themselves. The second may have developed the point of view that the problems people have are often caused by forces and events beyond their control. The reasoning of these two people, in terms of their inferences and assumptions, could be characterized in the following way:

Person One	Person Two
Situation: A man is lying in the gutter.	Situation: A man is lying in the gutter.
Inference: That man's a bum.	Inference: That man is in need of help.
Assumption: Only bums lie in gutters.	Assumption: Anyone lying in the gutter is in need of help.

Critical thinkers notice the inferences they are making, the assumptions upon which they are basing those inferences, and the point of view about the world they are developing. To develop these skills, students need practice in noticing their inferences and then figuring the assumptions that lead to them.

As students become aware of the inferences they make and the assumptions that underlie those inferences, they begin to gain command over their thinking. Because all human thinking is inferential in nature, command of thinking depends on command of the inferences embedded in it and thus of the assumptions that underlie it. Consider the way in which we plan and think our way through every-day events. We think of ourselves as preparing for breakfast, eating our breakfast, getting ready for class, arriving on time, leading class discussions, grading student papers, making plans for lunch, paying bills, engaging in an intellectual discussion, and so on. We can do none of these things without interpreting our actions, giving them meanings, making inferences about what is happening.

This is to say that we must choose among a variety of possible meanings. For example, am I "relaxing" or "wasting time?" Am I being "determined" or "stubborn?" Am I "joining" a conversation or "butting in?" Is someone "laughing with me" or "laughing at me?" Am I "helping a friend" or "being taken advantage of?" Every time we interpret our actions, every time we give them a meaning, we are making one or more inferences on the basis of one or more assumptions.

As humans, we continually make assumptions about ourselves, our jobs, our mates, our students, our children, the world in general. We take some things for granted simply because we can't question everything. Sometimes we take the wrong things for granted. For example, I run off to the store (assuming that I have enough money with me) and arrive to find that I have left my money at home. I assume that I have enough gas in the car only to find that I have run out of gas. I assume that an item marked down in price is a good buy only to find that it was marked up before it was marked down. I assume that it will not, or that it will, rain. I assume that my car will start when I turn the key and press the gas pedal. I assume that I mean well in my dealings with others.

Humans make hundreds of assumptions without knowing it - without thinking about it. Many assumptions are sound and justifiable. Many, however, are not. The question then becomes: "How can students begin to recognize the inferences they are making, the assumptions on which they are basing those inferences, and the point of view, the perspective on the world that they are forming?"

There are many ways to foster student awareness of inferences and assumptions. For one thing, all disciplined subject-matter thinking requires that students learn to make accurate assumptions about the content they are studying and become practiced in making justifiable inferences within that content. Here are some examples: In doing mathematics, students make mathematical inferences based on their mathematical assumptions. In doing science, they make scientific inferences based on their scientific assumptions. In constructing historical accounts, they make historical inferences based on their historical assumptions. In each case, the assumptions students make depend on their understanding of fundamental concepts and principles.

As a matter of daily practice, then, we can help students begin to notice the inferences they are making within the content we teach. We can help them identify inferences made by authors of a textbook, or of an article we give them. Once they have identified these inferences, we can ask them to figure out the assumptions that led to those inferences. When we give them routine practice in identifying inferences and assumptions, they begin to see that inferences will be illogical when the assumptions that lead to them are not justifiable. They begin to see that whenever they make an inference, there are other (perhaps more logical) inferences they could have made. They begin to see high quality inferences as coming from good reasoning.

We can also help students think about the inferences they make in daily situations, and the assumptions that lead to those inferences. As they become skilled in identifying their inferences and assumptions, they are in a better position to question the extent to which any of their assumptions is justified. They can begin to ask questions; for example: Am I justified in assuming that everyone eats lunch at 12:00 noon? Am I justified in assuming that it usually rains when there are black clouds in the sky? Am I justified in assuming that bumps on the head are only caused by blows?

The point is that we all make many assumptions as we go about our daily life and we ought to be able to recognize and question them. As students develop these critical intuitions, they increasingly notice their inferences and those of others. They increasingly notice what they and others are taking for granted. They increasingly notice how their point of view shapes their experiences.

The purpose of providing this detail is to stress the importance of experience. Academically, the Engineer has gained the skill of being able to think, to apply a sense of rationality to judgment. However, the accuracy of inferences is enhanced by experience in the environment in which the Engineer practises. If for no other reason, this justifies the need for the Engineer to “get experience” to develop into an effective practitioner. Candidates are referred to the Reference section for a wide reading on critical thinking.

It is therefore important that the Candidate accepts that after graduating, he or she is “not yet an Engineer” in the true meaning of the term. They are, however, from the tertiary education process, well-equipped to develop into one by the addition of experience, utilizing the process of judgment that was practiced during the academic phase.

So we can appreciate that good judgment is achieved by being well equipped to think and reason and being the benefactor of as much experience as possible gained within the workplace environment. The profession has hence realised how critical it is for the Candidate to fully exploit the candidacy phase of development, and that the processes integral to the programme have been constructed to optimize the options for the Candidate.

1.6. Cause and Effect Analysis

Within the built environment, Engineers are expected to be the masters of relating the causes and effects of the circumstances existing in that built environment. Engineers have been reared on a diet of the laws of nature/science and hence develop an expertise that enables them to relate how these laws apply to everything we experience. The advantage, in one respect, is that the laws are inviolate, and hence a benchmark of dependency exists. Compare this to the socially developed rules that apply to most other professions. Engineers cannot “manipulate” the laws of nature to suit social or political options. The laws are laws and thus, in another respect, they are a hard task master, ensuring that the reasoning and judgment of the Engineer are rational and logical.

A standard feature of all problems that the Engineer is required to resolve is, in essence, the requirement to connect cause and effect. For any Engineer this must be the most exciting challenge he or she faces and hopefully one in which the Engineer indulges happily, as it requires the accumulation of education and experience forming the basis of his or her daily activities, together with the satisfaction of resolving a complex problem in an organised way.

The basis of good judgment in linking cause and effect is the reasoning ability of the Engineer. Various tools exist that can facilitate the process, and assist in handling the data and information supporting events that need resolution.

Human nature does, however, impact on the required rationality in such circumstances, and the Candidate is referred to Outcome 1 where these are discussed. In particular, the following reference should be noted:

> *Beware of being "trapped" in a traditional intuitive or instinctive mindset, that might appear rational, but lacks the structured thinking processes that are required for good problem analysis. By intuitive and instinctive mindset, we refer to the common habit of "jumping to a conclusion" about the reasons for the problem, before allowing a more structured evaluation process. In this mindset, a solution is also derived which is frequently invalid. Life offers many instances of this "badly assumptive" process; it is often influenced by the psychological need for display of ego or authority. The comment often made in jest - "I have made up my mind, do not confuse me with facts" - while comic, often describes the reality.*

1.7. Current and Future Reality Analysis

There is a considerable amount of information on the tools that fall into the category of Root Cause Analysis (RCA). Reference is made to many methods used in 1.2., above.
One of the most effective methods to resolve cause and effect challenges is the construct that the Theory of Constraints (TOC) school calls the "current reality tree". This is the process of listing all the known effects in a free body form, and then linking the most obvious string of causes and effects, with the aim of identifying one event that is the cause of the others. This is a very convincing way of ensuring that symptoms are not mistaken for causes. It provides a graphical display of all the events or symptoms that the mind cannot easily provide on its own. Each link is then studied and evaluated

on its own so that in the end state, the logic is rational and objective. The process then moves on to enable resolution by the use of the remaining tools in the TOC suite.

1.8. Simplifying Complex Situations

Simplicity usually lies behind the problems we deem to be complex. The apparent complexity is largely a result of the way in which our mind observes the problem as presented. The methodologies referred to in the above sections provide some of the tools we can use. The common feature of them all is that the they enable us to identify the relevant issues that we need to attend to, and to remove those that are results of those on which we need to focus.

In Eli Goldratts' last book, The Choice, he identifies four issues that we need to observe and act on when confronted with our life's challenges. The Candidate considering applying new methods to add to his or her professional development portfolio should consider the following:

- We see reality as complex, rather than (as Newton showed) a thing of inherent simplicity
- We accept conflicts as a given, rather than seeking to remove them
- We blame, rather than assuming goodness and looking for explanations of other people's behaviour
- We think "we know", rather than challenging our assumptions and looking for breakthrough ways to change a situation

Various definitions of what constitutes a complex engineering problem have been developed. When we observe the problem we are invariably identifying symptoms that hence make the reality appear complex, as our mind cannot assemble the current reality represented by these. Why then is there a belief that inherent simplicity prevails?

The belief is that if you find the root cause, all the symptoms will vanish, and the reality will appear in an inherently simple form.

The Candidate is encouraged to give serious consideration to embracing the four items shown above that are lessons from The Choice.

GROUP DISCUSSION

INITIAL TEST

Complete the Initial Test in Appendix 1 (10 minutes are allocated for this).

SECTION 2

PRACTICAL DECISION-MAKING MODEL

LEARNING OUTCOMES:

- Understand the practical steps to be taken in order to exercise sound judgment in the course of complex engineering activities
- Be competent in using these steps
- Be prepared to apply this process in the workplace on a regular and routine basis

2. A PRACTICAL DECISION-MAKING MODEL

The Candidate should have reviewed the contents of Section 1 before proceeding to carry out the steps in this section. Note that each of these steps is aligned with the respective assessment criterion, as listed below:

STEP 1: Consider several factors, some of which may not be well-defined or may be unknown
STEP 2: Consider the interdependence, interactions, and relative importance of factors
STEP 3: Foresee consequences of actions
STEP 4: Evaluate a situation in the absence of full evidence
STEP 5: Draw on experience and knowledge
STEP 6: Justify judgments on risk associated with decisions

STEP 1: Consider several factors, some of which may not be well-defined or may be unknown

Making judgment requires that the processes identified in all the Outcomes 1 to 8 are taken into account. Each of these processes will have yielded evidence related to a complex engineering activity. Judgments will have been made progressively in the actions of analysis, solution development, making assumptions, drawing inferences, relating cause and effect, applying advanced knowledge, applying ethical standards, accessing and applying statutory and regulatory requirements, the effectiveness of communications and levels of responsibility.

Judgment ability and accuracy develops with practice because experience becomes the "evidence of past judgment" upon which future judgment will depend. The Candidate's exposure and application of the other Outcomes will assist in providing experience and methodology.

EXERCISE/ TOPIC FOR GROUP DISCUSSION

(These exercises/topics for group discussion can be done outside the workshop, as the time allocated will not allow for their completion at the workshop.)

In order to demonstrate this sequence of judgmental actions, the Candidate is required to identify a complex engineering problem challenge that has been undertaken and to prepare a list of decision-making judgments with their respective supporting reasons. Try to identify where such decisions were influenced by any of the Outcomes in this programme.

STEP 2: Consider the interdependence, interactions, and relative importance of factors

Safety factors exist in the life of the Engineer due to the inevitable influence of variability and uncertainty. The Candidate needs to be aware that when Engineers talk of safety factors these are not applied only to stress calculations and applications of strength factors. "Safety factors" is a generic term and should be considered when any system (complex engineering problem) requires protection from the variability and uncertainty present in its environment so as to ensure that its meets its defined purpose. This, of course, becomes a compromise as to how much over-design or over-provision is reasonable taking into account the expected working conditions, including paying attention to the life-cycle of the system. Think of the safety factor as a system buffer that protects the system from break-down, instability or collapse, having an impact on human safety as a result of an excursion.

EXERCISE/ TOPIC FOR GROUP DISCUSSION

Identify a project or projects where the design of a system requires consideration and application of safety factors in the assumptions. Explain the rationale for this, the assumed types of deviation from operational norms and how you provided for these.

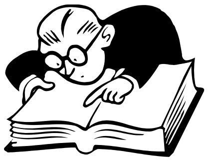
STEP 3: Foresee consequences of actions

The evidence of poor judgment is all too common. It is the result of deficiency of design, manufacture, construction or use, such as maltreatment and lack of maintenance.

The Engineer is charged with creating a built environment and hence is constantly challenged by the effect of natural degradation or what in thermo-dynamics we have termed entropy. Aside from this effect, there is the risk that we have misjudged the safety factors, or selected the wrong materials, or failed to provide for the mal-treatment by the users beyond expected norms.

Fortunately, most of the judgments made by Engineers are economical, safe and meet the intended goals. Engineers employ standards and codes developed from first principles and supported by experience, and which normally have a process of review at prescribed periods by the committees of experts that established them. These then draw on the cumulative experience and judgment of Engineers over time, thus providing a strong degree of assurance against variability and uncertainty. Where these do not exist, the Engineer then draws on his empirical expertise: methods of defining, investigating, analyzing and solving problems using theory and practice gained from experience.

Risk assessment has to be applied to interrogate the proposed solution. When Engineers contemplate the consequences of making judgments in respect of the lifecycles of their developments, attention has to be given to influences of factors beyond the design and initial creation. This may involve procedural specifications for operations, maintenance, and replacement. Thus, consequences of the Engineer's judgment are far-reaching and whilst in many instances negative ones are not a direct result of the original judgment, awareness of the overall impact needs to be considered.



EXERCISE/ TOPIC FOR GROUP DISCUSSION

Identify a situation where you have been required to find a solution to a problem and have applied an analysis of the possible consequences of the decisions made over the life cycle of the solution. Have these included any mitigating factors that are to be followed to increase the assurance of meeting the required end state?

STEP 4: Evaluate a situation in the absence of full evidence

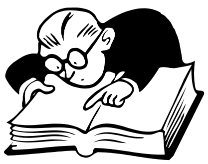
Engineers generally live by the ethos that you really only know about something if you can measure it. Accordingly, if a future risk is envisaged this should be defined by quantifying and qualifying it and describing its potential impact on all affected systems. These projections are invariably subject to assumptions and probability-driven data. However, carrying out this process should generate an awareness among those that could be affected, thus introducing any precautionary measures in anticipation of such risks.

For the exercise carried out in Step 3, the Candidate is to identify the foreseen risks and to describe them by qualification and extent. Include measures that should be taken in the future to mitigate the risks.

A Basic Risk Matrix

Likelihood	Impact				
	Insignificant	Minor	Moderate	Major	Severe
Almost certain	Moderate	High	High	Extreme	Extreme
Likely	Moderate	Moderate	High	High	Extreme
Possible	Low	Moderate	Moderate	High	Extreme
Unlikely	Low	Moderate	Moderate	Moderate	High
Rare	Low	Low	Moderate	Moderate	High

The main benefit of the risk matrix is that it provides a visual display that differentiates high-probability/ low-impact and high-impact/ low-probability risks. Because multiple risks can be displayed simultaneously, the approach benefits from the comparative ease that people have in making pair-wise comparisons as opposed to the greater difficulty associated with drawing absolute judgments. Within a risk management process, the matrix provides documentation demonstrating that risks have been identified and deliberately evaluated. Also, the matrix can be used to show how the likelihood and impact of risks change and therefore move within the matrix, for example, over time at different stages in a project's investment life cycle or as a result of candidate risk-mitigation strategies.



EXERCISE/ TOPIC FOR GROUP DISCUSSION

Can the candidate identify a project in his or her organisation where a risk evaluation matrix could be developed by the candidate that would require the candidate, interacting with the project team, to address this aspect either as grassroots development or by reviewing and providing a commentary on the existing risk-mitigation process?

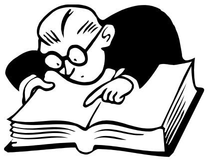
GROUP ACTIVITY

Select one or more of the exercises/ topics for discussion mentioned above, for group discussion.

STEP 5: Draw on experience and knowledge

An Engineer, as with any professional, develops competence by increasing technical, legal (in the form of statutory requirements), social and cultural knowledge and applying them using professional skills. As important as having one's own knowledge, is the wisdom of knowing when to seek advice from others in the form of experts and references. In the candidacy phase of the Engineer's training, on which this programme is focused, the roles of the Mentor and the Supervisor have been seen as crucial, and as the Candidate develops a relationship with them, he or she should learn the balance between own knowledge and the need to ask. The candidate should follow the adage that there is never a stupid question, only a stupid answer. However, the framing of the question must be such that it addresses the problem clearly.

It is necessary to be aware of the best sources of expertise and advice. There are no fixed rules on this and today one has to be vigilant of the plethora of options that are freely available, for example on the internet, and to be cautious in regarding all the information thereon as factual and appropriate. The Engineer will realise that in the profession, the process of peer group review and judgment is really the only dependable way to find the benchmark level. Aggregation of ideas will inevitably be more reliable than a single source. Ultimately, the Engineer will need to make a judgment call and the processes learnt and practiced in this programme should enable this to be as robust as possible.



EXERCISE/ TOPIC FOR GROUP DISCUSSION

The candidate is required to provide a report explaining where on one or more projects he or she sought out expert advice or references and how, in the formation of the solution, this input was used and judged. Describe how the experts or references were selected.

STEP 6: Justify judgments on risk associated with decisions

This activity will be the test of the process used by the Engineer to evaluate the extent or degree of risk associated with a proposed solution. It will inevitably involve the interrogation by others because it has brought the project to finality. The rationale will have to be available and clearly justified. The Engineer should be quantifying the risk associated with the solution over its lifecycle. It will be the time for bold confidence in the analysis and synthesis used to reach the solution. All too often the projection of risk on a quantified basis is not bounded by specific measures. A statement such as the following is, in real terms, meaningless: “The plant discharge will need to be monitored for acidity on a regular basis”. Two risk metrics are undefined here: the level of acidity limits or range is not stated, and the frequency of “regularly”.

Thus this would best be stated: “The plant discharge must be monitored every 12 hours and the acidity level must be limited to a pH not exceeding 6. Should this at any time be reached, the plant discharge must be redirected to the holding tanks and the reasons for the excursion determined in accordance with procedure number xx”. This approach defines the appropriate metrics, the mitigating action and the corrective action required. The risk is thus managed.

ASSESSMENT TEST

Complete the Assessment Test in Appendix 1 (30 minutes are allocated for this).

GROUP ACTIVITY

Report and 10 minute presentation evaluation.

CLASS DISCUSSION

Discuss Case Studies (Appendix 2) and Programme administration.

SECTION 3

GENERIC GUIDING PRINCIPLES

GENERIC GUIDING PRINCIPLES

1. Competency Standard

The SAIMechE Competency Standard is the fundamental document underpinning the journey to Professional Competence. It is the foundation document informing all aspects of the training programme that relates the requirements of competency to the working environment of the developing engineer. It is the standard of practice against which all activities of a competent and professional engineer is measured.

2. Outcomes

The eleven outcomes are the fundamental building blocks on the path to competency. A demonstration of understanding of these outcomes as they relate to the day-to-day working environment will indicate that a level of competency has been reached which will enable the candidate to function at a professional level within the commercial and business environment.

3. Assessment Criteria

The assessment criteria are the requirements against which the candidate is evaluated in order to determine understanding and competency. These are objective criteria which will ensure capability and transparency and set a standard that ensures a proficient level of competency and professionalism as required by industry and in the interests of public health and safety.

4. Range Statements

The range statements set the boundaries of the requirements of each outcome and determine the limits of competency as required for professional practice.

APPENDICES

APPENDIX 1: ASSESSMENTS/TESTS/EVALUATIONS

INITIAL TEST (SECTION 1)

1. What learning processes are used during the education phase up to degree level that enable the Candidate to acquire the skills of judgment? How does the practising Engineer determine whether any judgments made in resolving solutions are “correct”?

2. What are the origins of the words “analysis” and “synthesis”? Define the meaning of the terms in your own words.

3. What is the right way to start off seeking a solution to a complex engineering problem?

4. Name 5 common-use problem solving tools, and describe in some detail two of them

5. Give definitions of “data”, “information” and “knowledge”. In what way are they related?

6. Where does one start in acquiring the material for solving complex problems?

7. Describe what you understand a “safety factor” to be. What principles lie behind the application of a safety factor in any design or process?

8. What are the two features that render safety factors to be necessary?

9. Describe how safety factors have evolved over time and how they are incorporated into the Engineer’s reference material.

10. Describe what you understand to be an assumption, an inference and the relationship between the two.

11. Describe any situation where you have observed that two people, witnessing the same event, have evaluated the situation with opposite inferences. On what basis did this happen?

12. How would you proceed to establish a link between a set of observed symptoms and root cause in a situation where you have been requested to find a solution?

13. What do you believe is the most predominant reason for Engineers making incorrect judgments when challenged with a complex engineering problem?

14. How do you react to the statement “We see reality as complex, rather than (as Newton showed) a thing of inherent simplicity?

15. How do you react to the statement “We think "we know", rather than challenging our assumptions and looking for breakthrough ways to change a situation?

16. What are the 4 levels of activity that generally precede the Engineer reaching that of *performing* (the highest level of responsibility)?

17. How do you envisage the Engineer's Code of Conduct applying to the role of the Engineer?

ASSESSMENT TEST (SECTION 2)

1. You have been asked to identify a complex engineering problem to use as a project to demonstrate competence. What factors would you use to select such a problem?

2. Give some examples of your understanding of protecting a component and a system from failure by the use of safety factors. Present your reasoning.

3. Are you able to identify any engineering project or result of the engineering role on a project where, from your observer role, you consider there has been an evident example of poor engineering judgment?

4. We have illustrated a typical risk matrix comparing likelihood of event versus impact. Do you see this as a mechanism that you could use in the future? Have you applied, or are you familiar with, any other such risk assessment support systems?

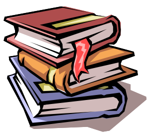
5. You are responsible for certain engineering input to a project, and there is a need to consult experts (that are not involved in the project itself) or expertise from any source. How would you proceed to identify this requirement?

6. Risks associated with poor upkeep of an original asset or facility are common. Identify where, in your judgment, there are any significant cost and safety-related risks associated with the infrastructure in South Africa.

7. Are you able, in your own words if necessary, to recall and list below the 6 assessment criteria that apply to Outcome 9?

APPENDIX 2: CASE STUDIES

REFERENCES



Interesting websites for further study

Systems engineering: an introduction
http://www.npd-solutions.com/se.html

Mechanical Engineer's DSTG document
http://www.ecsa.co.za/documents/NewReg/R-05-MEC-PE.pdf

Problem solving techniques for teams
http://www.reliableplant.com/Read/14690/high-performance-team

The critical thinking community
http://www.criticalthinking.org/pages/critical-thinking-distinguishing-between-inferences-and-assumptions/484

Miniature guide to critical thinking
http://think.hanover.edu/Resources/MiniGuidetoCT.pdf

Cognitive processes
http://www.learner.org/series/discoveringpsychology/10/e10expand.html

RCA and the TOC tools
http://www.dbrmfg.co.nz/Thinking%20Process%20CRT.htm

Project portfolio risk management
http://www.prioritysystem.com/reasons4.html

RECORDING OF REPORTS

Formats for recording the portfolio of evidence

During the course of the candidate phase training, the Candidate will accumulate a portfolio of evidence comprising the reports supporting the various exercises covered in these guidelines for each Outcome.

Note that the PDP Administration will provide a web site document system that will allow the candidate to store all the PDP documents created as a back-up facility and will enable the candidate to allow access by the Mentor for any reviews that are required.

ASSESSMENT PROCESS

Guide to the Candidate

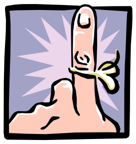
You will be assessed against Outcome 9.

In order to determine your level of competence you will be tested by:

- Tests done during the workshop and evaluated by fellow candidates and your mentor
- Written assignments (practical tasks given to demonstrate understanding of this Outcome through application in a work setting)
- Knowledge assessment and presentation (i.e. 10 minutes oral presentation using Power Point). Please Note: Oral presentations may need to be taped for moderation and re-assessment procedures.

You will need to prepare yourself in the following ways:

- Familiarise yourself with the contents of this guideline
- Familiarise yourself with the reporting formats required
- Familiarise yourself with the references listed
- Do the written assignments as required by this workshop
- For oral presentations of reports, a ten minute presentation is required to summarise the exercise performed



Note:

A detailed briefing on the exact requirements was given to you by the Mentor/Assessor at the Introductory Workshop in order for you to prepare for the assessment process.

The evidence you will be judged on includes:

- Your proven competence in all areas questioned in the presentation (Competent or Not Yet Competent)
- The practical tasks compiled in your Portfolio of Evidence

Good luck, and remember, the mentor/assessor is there to help you.