

**Course:**                    **Introduction to Engineering**

**Unit:**                        **Ethics and Safety in Engineering**

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## **1. INTRODUCTION**

### ***1.1 IMPORTANCE OF ETHICS AND SAFETY FOR ENGINEERS***

- Ethics and safety are two related topics of great importance for engineers.
- These two topics define some of the most important interfaces between engineers and the environment in which they operate.

### ***1.2 SCOPE OF THIS LECTURE***

- In this lecture, the following aspects of engineering ethics are briefly addressed:
  - \* Facets and tenets of ethics for engineers.
  - \* How to settle conflicts arising from ethical questions.
  - \* Allocation of resources in an ethical manner, and how to calculate the cost of a life from an engineering viewpoint.
  - \* Effects of a person's locus of control on his/her ethics.
- The following aspects of safety in engineering are also introduced:
  - \* Formal methods to determine system hazards and safety.
  - \* Risk management.
  - \* The use of safety factors and redundancy.

## **2. ENGINEERING ETHICS**

### ***2.1 FACETS AND TENETS OF ETHICS***

- There are various facets of ethical behaviour, e.g.:
  - \* Accepted standards of right and wrong (morals) – which depend on cultural and religious background.
  - \* Interaction rules aimed at avoiding or resolving conflicts.
  - \* Etiquette: good manners, manifested as courtesy and respect for others (clients, employers, colleagues, friends, family, general public, etc.).
- Engineers have an obligation to always behave ethically towards their clients, employers, colleagues, and the general public.
- In many projects, the client and the public do not have the expertise to assess the engineers' advice, and so must "trust" that advice.
- The engineering profession has a strong tradition of upholding ethical practices, and most engineering organizations have their own Code of Ethics.
- Tenets of the Code of Ethics (Engineers Australia):
  1. Members shall place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests, or to other members.

2. Members shall act with honour, integrity and dignity in order to merit the trust of the community and the profession.
  3. Members shall act only in areas of their competence and in a careful and diligent manner.
  4. Members shall act with honesty, good faith and equity and without discrimination towards all in the community.
  5. Members shall apply their skill and knowledge in the interest of their employer or client for whom they shall act with integrity without compromising any other obligation to these Tenets.
  6. Members shall, where relevant, take reasonable steps to inform themselves, their clients and employers, of the social, environmental, economic and other possible consequences which may arise from their actions.
  7. Members shall express opinions, make statements or give evidence with fairness and honesty and only on the basis of adequate knowledge.
  8. Members shall continue to develop relevant knowledge, skill and expertise throughout their careers and shall actively assist and encourage those with whom they are associated, to do likewise.
  9. Members shall not assist in or induce a breach in these Tenets and shall support those who seek to uphold them if called upon or in a position to do so.
- Like other citizens, engineers must also act lawfully at all times.
  - This includes respecting the intellectual property rights (e.g. patents and copyright) of others.
  - There is a variety of laws (made by different levels of government) that influence an engineer's work; and it is important to be "legal wise".

## **2.2 SETTLING CONFLICTS**

- A major part of engineering involves balancing cost, schedule and functional requirements.
- This often leads to conflicts, which need to be resolved.
- Other sources of conflict can include:
  - \* Moral - alternative social positions; these can be difficult to resolve. E.g. Is it right or wrong to work in the defence industry?
  - \* Uncertainty in converting a moral position into a rule – where to draw the line between right and wrong?
  - \* Uncertainty in how to apply the rule - grey areas in the interpretation of a rule.
  - \* Uncertainty in facts behind the conflict.
- There are different moral theories, which provide frameworks for making moral and ethical decisions, e.g.:
  - \* **Ethical egoism** - act in enlightened *self-interest* (not selfishness). E.g. killing a mugger who attacks you is done to protect self-interest, but does not stem from selfishness.
  - \* **Rights analysis** – universal rules having equal respect for all human beings. An example of a universal rule is the *Golden Rule*: Do unto others as you would have them do unto you.

- \* **Utilitarianism** – act to bring *the most good to the most people*.
- The different theories may lead to the same or to different answers.
- What if the answers diverge?
- Example 1 (Holtzapple & Reece 2005)
  - \* Building a freeway through a residential area.
  - \* The decision-maker will have a dilemma with: I wouldn't want the freeway to pass through my house. Do unto others as you would have them do unto you. The freeway will make a lot of people happy, and some unhappy.
  - \* There is no right or wrong answer .....
  - \* However, the utilitarian principle will usually win over the rights of the individuals.
- Example 2 (Warburton 1999)
  - \* *Always tell the truth* and *Protect my friends*
  - \* Now, if a madman carrying an axe asks you where your friend is, what do you tell him?
  - \* Once again: the utilitarian principle will help the decision-making process.
- A **conflict of interest**: is a situation where an engineer's loyalties and obligations may be compromised because of self-interest or other loyalties or obligations.
- This can lead to biased judgements, e.g.:
  - \* A civil engineer is busy designing a new waste disposal site.
  - \* He manipulates the decision criteria such that the best site seems to be a friend's recently acquired farm, from which the friend stands to make a good profit should the government buy it for the disposal site.
  - \* This situation is a clear conflict of interest.
- Informing authorities of harmful, dangerous, or illegal activities is often called **whistle blowing**.
- An engineer involved with an organisation doing such activities has a conflict of interest: should he be loyal to his employer or to society?
- There are consequences to be considered: effects on self, family, company, and the public.
- It is always best to try and solve the problem internally (without covering up), but if that doesn't work, then the obligation is to blow the whistle.
- Solving the problem internally might require extensive negotiation skills – for which there are various techniques. (GOUWS & GOUWS 2006a provide a framework for preparing for negotiations.)

## **2.3 RESOURCE ALLOCATION**

- (Based on discussion by Holtzapple & Reece 2005.)
- One of the greatest challenges to society is proper allocation of resources.
- Misallocated resources can cost lives.
- Consider well-meaning legislation to reduce carcinogens released by chemical industry.

- If, for example, the chemical industry would spend \$1 billion to reduce carcinogens to save one person's life, would that be proper allocation of resources?
- For the person saved, the answer is yes!
- Others might say the money could have been better spent elsewhere.
- The big question is: "What is the value of a human life?"
- One might say it is invaluable, but that doesn't help society to make decisions on resource allocation.
- We make decisions on the value of our own lives, by the choice of car we drive.
- During an assumed ten year life of a car, the fatality rate from driving an average car in average conditions is 1 death per 700 drivers.
- The rate of fatalities for a luxury car with advanced safety features is 1 death per 1400 drivers.
- If the price of the average car is \$20000, and for the luxury car is \$60000,  
and if you intend to own either car for 10 years,  
and if you decide to buy the average car,  
then what price have you put on your life?
- *Answer:*
  - \* If 1400 people buy the average car then the total price is \$28,000,000; which leads to 2 deaths over a 10 year period.
  - \* If, instead, 1400 people buy the luxury car then the total price is \$84,000,000 for 1 death.
  - \* So the value placed on one life is \$56,000,000!
  - \* If you know this figure, and you still buy the cheaper car, you value your life at less than \$56 million, since you could become the extra fatality.
- The conclusion from the above is that life has a value, and engineers need to be able to make these sums in order to act rationally, ethically, and economically.

## ***2.4 LOCUS OF CONTROL***

- Ethics is often influenced by a person's "locus of control".
- Persons with internal locus of control:
  - \* Believe they are self the source of outcomes.
  - \* Seek self improvement.
  - \* Take responsibility for their own actions.
  - \* Prefer to be part of decisions which affect them.
  - \* Are attracted to work with potential for personal achievement.
  - \* Take quick action to correct job confusion and problems.
  - \* Search for new knowledge which will lead to valued outcomes.
  - \* Are comfortable with change.
- Persons with external locus of control:
  - \* Believe outcomes are created by forces and events outside themselves.

- \* Are likely to experience adverse reactions to supervisors who exert job pressure.
- \* Believe promotion and raises are functions of luck and being in the right place at the right time.
- \* Believe more in favouritism than in own performance.
- External locus of control people are often less inclined to act ethically or to be whistle blowers, since they believe situations are thrust upon them, and that they have very little control over it.
- In order to act ethically, it is important to take responsibility for one's own actions.
- ***If you muck up, you own up, and we fix up!!***

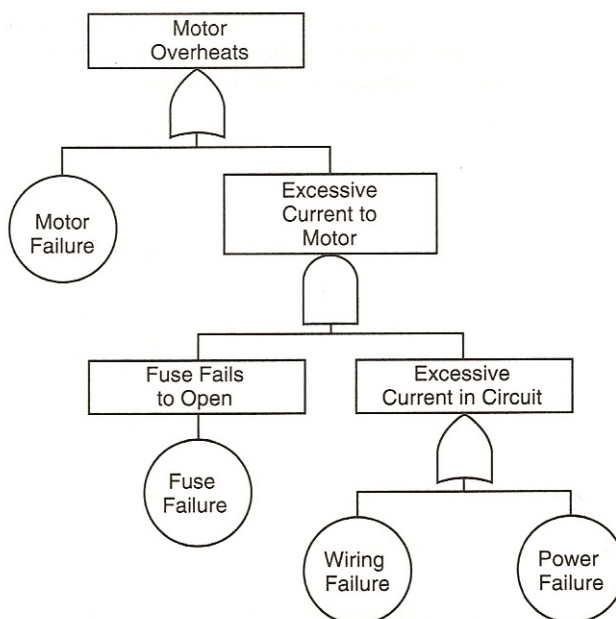
## **2.5 CASE STUDY**

- The *Challenger* was one of the three space shuttles launched by NASA.
- A space shuttle is a reusable delta wing orbiter for space travel.
- The shuttle makes use of two solid-fuel booster rockets for the first two minutes of flight.
- These boosters are jettisoned once they are no longer needed.
- The booster rockets are large (approximately 45 m long, 3.7 m diameter), and are assembled from smaller sections, which are sealed with O-rings and special putty.
- These seals had been a source of difficulties for a long time, since combustion gases could blow out past the seals.
- Engineers knew this to be a problem - especially during cold weather.
- In order to justify the costs of the programme, NASA was under huge political pressure to undertake very frequent shuttle missions.
- On January 28, 1986, disaster struck!
- Despite an engineer recommending that the launch should not take place, because of likely seal problems due to very cold weather, the decision was made to go ahead with the launch.
- After 76 seconds, the booster rocket joints failed, allowing combustion gases to blow out, and to ignite the shuttle's hydrogen fuel.
- A fatal explosion followed, destroying not only the shuttle but also all seven astronauts on board!
- Ethical questions:
  - \* Should the engineers have blown the whistle, instead of just recommending that the launch be delayed?
  - \* Should the astronauts have been informed about the increased risk?
  - \* Which moral theory were the contractor and NASA using when they decided to go ahead with the launch? Ethical egoism, utilitarianism or rights analysis?
  - \* If we now judge the decision-makers retrospectively as being wrong, what moral theory are we applying?
  - \* Is it unfair to place the blame on the NASA managers?
  - \* Should the engineers who designed the seal be blamed?

## 3. SAFETY IN ENGINEERING

### 3.1 SAFETY

- Safety is related to ethics: *Members shall place their responsibility for the welfare, health and safety of the community before their responsibility to sectional or private interests, or to other members.*
- Safety is often addressed as part of so-called OSHE (or OSH&E) – occupational safety, health, and environment.
- From an engineering viewpoint, safety is a major concern for both personnel and for equipment.
- It is important to keep a history of previous events that had an impact of safety (positive or negative) in order that future designs can benefit from this.
- One form of keeping adequate history for this purpose is to compile a Failure Reporting, Analysis, and Corrective Actions (FRACAS) report.
- KLETZ 1999 provide numerous historical examples of things that have gone wrong in different plants and processes – from which much can be learned.
- There are various formal methods of hazard identification and analysis which can be applied by engineers, of which some examples are briefly discussed below.
- Most of these methods rely heavily on statistical analysis.
- Fault tree analysis:
  - \* Identify combinations of modes or conditions that produce hazards.
  - \* Combinations of contributory events.
  - \* Probability that an undesired event will occur can later be calculated.
  - \* Example (taken from KUMAMOTO & HENLEY 1996):





- Failure Modes, Effects, and Criticality Analysis (FMECA):
  - \* Predicting potential failure modes (initiating events or accident initiators), their effects, and their criticality.
  - \* The three most commonly encountered failure types are related to:
    - ◆ equipment (hardware, software, and data);
    - ◆ humans (operator errors, design errors, maintenance errors, etc.); and
    - ◆ the environment (earthquakes, lightning, floods, etc.).
  - \* Mainly used to analyse the effects of single source failures. (The effects of multiple simultaneous failures are better analysed by means of fault-tree analysis.)
  - \* Because the FMECA can become very extensive, it is sometimes done in two phases: failure modes and effects analysis (FMEA) and criticality analysis (CA).
  - \* GOUWS & GOUWS 2006b provide an example of a framework for an FMECA report.
- Reliability Engineering
  - \* Predicting the reliability and safety of systems is a huge engineering field on its own (e.g. RAMAKUMAR 1993).
  - \* Complex reliability models can be compiled for electronic circuits, mechanical components, chemical processes, etc.
  - \* As part of reliability calculations, parameters such as *mean time to failure* (MTTF) and *mean time between failures* (MTBF) can be calculated.

## ***3.2 RISK MANAGEMENT FOR ENGINEERS***

### **3.2.1 Introduction**

- An important part of designing with safety in mind is risk management.
- Risk can be defined as *a potential problem that will be detrimental to project success, should it materialise*.
- Risk management is a sub-set of project management, and should be addressed very specifically as part of any project management plan.
- Traditional project management often only addresses problems when they arise; while risk management is proactive.
- The two major aspects of a risk are its *probability* of occurrence and its *impact* (JONES 1995; KUMAMOTO & HENLEY 1996).
- Project risk is characterised by:
  - \* Uncertainty ( $0 < \text{Probability} < 1$ ).
  - \* A loss associated with it (money, time, reputation, product functionality, etc.).
  - \* It is manageable (human actions can be applied to change its form and degree).
- For proper risk management, outcomes that must be avoided (i.e. risks) must be stated explicitly in order to identify possible courses of action.
- Risk management can require substantial resources in order to reduce probabilities and impacts of

identified risk factors.

### **3.2.2 Risk Identification**

- Risks can't be managed before they've been identified and described in an understandable way.
- Risk identification involves an organized, thorough process of seeking out the most likely potential problems.
- It is useful to categorize risks in terms of the three "legs" of a project – i.e. functional-, cost-, and schedule risks.
- Functional risks include: inadequate functionality, poor reliability, low maintainability, etc.
- Cost risks include: overspending, inadequate resources, etc.
- Schedule risks include: loss of key personnel, schedule slip, etc.
- The nature of risks and the understanding of different risks evolve over time. Therefore risk assessment and –management is a continuous task.
- Risk identification involves analysis of aspects such as:
  - \* Expected and actual cost and schedule of previous projects.
  - \* Requirements documents, project assumptions, and project plans.
  - \* Results obtained from previous developments, and from current prototypes, simulation models and trade-off studies.
- Reducing schedule can have a high risk of increasing cost, or decreasing functionality.
- Budget cuts can have a high risk of increasing schedule (and thus increasing actual cost), or decreasing performance.
- Unrealistic budgets (low cost estimates made to satisfy the market, upper management, or clients) are a high-risk area.
- The following characteristics of project requirements increase risk:
  - \* Vague and/or incorrect (end product will not match client expectations).
  - \* Incomplete (extra work will be required to satisfy client expectations).
  - \* Inconsistent (conflicting requirements waste time to resolve).
  - \* Unverifiable (impossible to prove that such requirements have been satisfied).
  - \* Untraceable (requirements randomly appearing / disappearing during development).
  - \* Volatile (continuous changes make the requirements a moving target).
- Note that anything done to overcome the above problems will almost always increase cost and schedule.

### **3.2.3 Risk Analysis**

- Risk analysis requires examination of potential risks to determine their probabilities and impacts.
- A diversified team should regularly assess risk probabilities and impacts, in order to remove personal biases.
- A major problem in risk management is refusal to acknowledge that a risk has become a problem.

- Depending on its assessed impact and probability, each risk can be prioritised from 1 (low) to 5 (high), according to a matrix as shown below.
- Once prioritised, the risks can be addressed from high (5) to low (1) priority.

		Probability		
		Low	Medium	High
Impact	Low	1	2	3
	Medium	2	3	4
	High	3	4	5

**Typical Risk Priorities (1 = Low; 5 = High)**

- Besides analysing the probability and impact of each risk, and identifying potential risk handling actions (see next section), the following aspects should also be addressed:
  - \* Indicators that a potential problem is becoming a real problem.
  - \* Trigger events to watch out for.
  - \* Related areas of impact.

### **3.2.4 Options for Risk Alleviation**

- Once risks had been identified and prioritized, options for alleviating the risks must be found.
- Different options for doing this are discussed below.
- Risk avoidance:
  - \* Consciously seeking low risk options when decisions are made.
  - \* However, avoiding one risk (e.g. overspending) might increase another risk (e.g. decreased quality).
- Risk assumption:
  - \* Consciously accepting the possible consequences of a specific approach.
  - \* Accept low probability and low impact risks, and handle the consequences should they occur.
- Problem control (prevention):
  - \* Use various methods to prevent the risk from materialising.
  - \* Example: use a hard disk on a computer, knowing that it can fail, but make regular back-ups.
- Risk transfer:
  - \* Transfer risks from one area to another.
  - \* E.g. risk of high staff turnover can be transferred to subcontractors, by outsourcing.
  - \* However, that can bring new risks such as losing strategic internal abilities.
- Knowledge acquisition:
  - \* Reduce development uncertainty by obtaining more information.
  - \* Typical techniques: prototyping, simulation and modelling, incremental development, etc.

### **3.2.5 Cost of Risk Abatement**

- Risk management is a form of buying insurance.
- If a risk does not materialise, the project manager is often criticised for wasting resources on something that didn't materialize – e.g. the Y2K problem, which is now often called the “most expensive non-event in modern history”.
- Critics of risk management often conveniently forget that the very aim of successful risk management is to ensure that risks don't materialize.
- The best way to avoid being blamed for wasting resources on “non-events”, is to document the complete risk management process, and to calculate the cost-effectiveness of the actions.
- One method towards quantifying the cost-effectiveness of risk management:
  - \* Determine probability (P) of an undesired event.
  - \* Determine cost (C) of the loss if the risk becomes a problem.
  - \* Maximum amount (RE) that should be spent on risk management:  $RE = P \times C$ .
- Another technique is to examine the *risk leverage factor* (RL) that would result from mitigating the risk:
  - \*  $RL = [(exposure\ before) - (exposure\ after)] / (cost\ of\ risk\ management)$ .
  - \* “Exposure before”: potential cost impact of the risk before risk management.
  - \* “Exposure after”: potential cost impact of the risk after risk management.
  - \* Risk mitigation activities may reduce probability, impact, or both.
  - \* High values of RL indicate the best areas for investing in risk management.

### **3.3 SAFETY FACTORS AND REDUNDANCY**

- In order to improve safety in engineering designs, it is important to understand the underlying scientific principles of the design as well as the probabilities and the impact of failure.
- Two commonly used techniques to improve safety is to incorporate in the design:
  - \* A safety factor – e.g. to make a mechanical part ten times stronger than necessary.
  - \* Redundancy – i.e. have more than one component in parallel to perform a critical function.
- Incorporating these measures into a design often requires a careful trade-off, e.g.:
  - \* Using a safety factor in one area can have a negative impact on cost, or on other parameters such as mass – which can in turn negatively influence reliability in other areas of the design.
  - \* To implement redundancy often requires monitoring equipment to sense when the system should switch from one component to another. This adds extra complexity, and can sometimes reduce reliability and safety, instead of improving it.

## **4. REFERENCES**

Dym, C.L. & Little, P. (2004): *Engineering Design: A Project-Based Introduction*, Wiley

Gouws, J. & Gouws, L.E. (2006a): *Frameworks for Selected Business Management Reports Ebook*,

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Feedforward Publications ([www.melikon.com](http://www.melikon.com) → E-Bookstore); ESNB M01-175C-6885-77G3

**Gouws, J. & Gouws, L.E. (2006b):** *Frameworks for Selected System Engineering Reports Ebook*; Feedforward Publications ([www.melikon.com](http://www.melikon.com) → E-Bookstore); ESNB M01-175A-6885-77E1

**Holtzapfel, M.T. & Reece, W.D. (2003):** *Foundations of Engineering* (2<sup>nd</sup> Ed.), McGraw-Hill

**Jones, R.B. (1995):** *Risk-Based Management – A Reliability-Centered Approach*; Gulf Publishing

**Kletz, T. (1999):** *What Went Wrong? Case Histories of Process Plant Disasters*; Gulf Professional Publishing

**Kumamoto, H. & Henley, E.J. (1996):** *Probabilistic Risk Assessment And Management For Engineers And Scientists* (Second Edition), IEEE Press; ISBN 0-7803-1004-7

**Ramakumar, R. (1993):** *Engineering Reliability – Fundamentals and Applications*; Prentice-Hall

**Warburton, N. (1999):** *Philosophy: The Basics* (3<sup>rd</sup> ed), Routledge

## **5. SELF-ASSESSMENT**

### ***5.1 TRUE / FALSE QUESTIONS***

Indicate which of the following statements are TRUE and which are FALSE.

1. Good manners is one dimension of ethics that engineers should take care of.
2. Engineers should always assist their mates, even if that means breaching some minor tenet of ethics.
3. Balancing cost, schedule and functional requirements is the only real source of conflict of interest to engineers.
4. Utilitarianism is a moral theory aimed at bringing the most good to the most people.
5. Proper allocation of resources is an economic problem, with no major influence on engineering decisions.
6. Ethics is often influenced by a person's locus of control.
7. Persons with internal locus of control believe outcomes are created by forces and events internal to the environment.
8. Safety is related to ethics.
9. There are various formal methods of hazard identification and analysis which can be applied by engineers, of which some rely heavily on statistical analysis.
10. Fault tree analysis is the same as FMECA.

### ***5.2 MULTIPLE CHOICE QUESTIONS***

Choose the most correct answer for each of the following questions:

- 1) An examples of a facet of ethical behaviour is:
  - a) Accepted standards of right and wrong (morals).
  - b) Interaction rules aimed at avoiding or resolving conflicts.

- c) Etiquette.
  - d) All of the above.
- 2) Conflict in engineering can arise from:
- a) Similar social positions.
  - b) Uncertainty of where to draw the line between right and wrong.
  - c) Overconfidence in how to apply the rules.
  - d) All of the above.
- 3) Applying different moral theories should:
- a) Lead to the same or similar answers.
  - b) Be avoided, since that can lead to conflict.
  - c) Both (a) and (b).
  - d) None of the above.
- 4) Calculations to determine the value of a life are:
- a) Important in order to allow engineers to act rationally, ethically, and economically.
  - b) Important in order to allow engineers to have some fun in their work.
  - c) Superficial.
  - d) Part of the discipline *social engineering*.
- 5) Ethics is often influenced by a person's "locus of control", which implies:
- a) The boss decides what is right or wrong.
  - b) External influences dictate what will happen.
  - c) Don't try to beat the system. Just go with the flow.
  - d) Ethics are influenced by whether a person takes responsibility for his/her own actions.
- 6) From an engineering viewpoint, safety is a major concern for:
- a) Personnel.
  - b) Equipment.
  - c) Both (a) and (b).
  - d) None of the above.
- 7) The methods of hazard identification and analysis which can be applied by engineers include:
- a) Fault finding analysis.
  - b) Failure Modes, Effects, and Criticality Analysis (FMECA).
  - c) Reliability of Supply.
  - d) All of the above.
- 8) The major aspects of a risk are its:
- a) Statistical uncertainty and improbability.
  - b) Probability of occurrence and its impact.
  - c) Probability of occurrence and its probability of impact.
  - d) Association with money, time, reputation, product functionality, etc.
- 9) Risks must be managed:
- a) Whether they've been identified or not.
  - b) If other forms of insurance is not available

- c) Only if they relate to cost and safety simultaneously.
  - d) As soon as they've been identified.
- 10) Commonly used techniques to improve safety is to incorporate in the design:
- a) A safety factor.
  - b) Redundancy.
  - c) Both (a) and (b).
  - d) None of the above.

### **5.3 ESSAY QUESTIONS**

Write an essay of 300 to 400 words on one of the following topics. Do not merely copy the course notes, but write the essay **in your own words** such that your understanding of the topic becomes clear.

1. Do an internet search of different engineering organisations' code of ethics, and briefly discuss these.
2. Can the cost of life really be calculated?
3. Discuss different loci of control, and how that can influence a person's ethical stance.
4. Discuss options for risk alleviation in engineering.
5. Discuss whether incorporating safety factors and/or redundancy in a system design is always a good thing.

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