GNG 2101 Summary Sheet

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1 Design For X

Functional requirements define what a product should do. DFX (Design for X) allows us to ensure the product meets the certain requirements called X.

Non functional requirements are about How the product does what we want it do do such as the speed, and quality.

DFX allows us to focus on specific goals for the product, one at a time. We want to have discussions about "How do we incorporate X?". Each X has specific design standards and rules that help to incorporate this X.

Some examples are:

- Design for Accessibility
- Design for Reliability
- Design for Testability
- Design for Repairability
- Design for Compliance
- Design for Sustainability
- Design for Maintainability

1.1 Compliance

Compliance constraints are stuff such as health and safety regulations, environmental regulations, quality codes, and standards.

Often devices need to be able to use generic designs such as USB which means they need to comply with these preexisting standards. These standards are usually explained in technical documents.

Government regulations for environment, and health/safety are also critical to avoid fines.

1.2 Sustainability

1.2.1 Triple Bottom Line

Sustainability is a concept that depends on people, profit, and the planet. We need a product to satisfy all three of these concepts for it to be able to be sustainable which is challenging. So we need a balance between all three of these items.

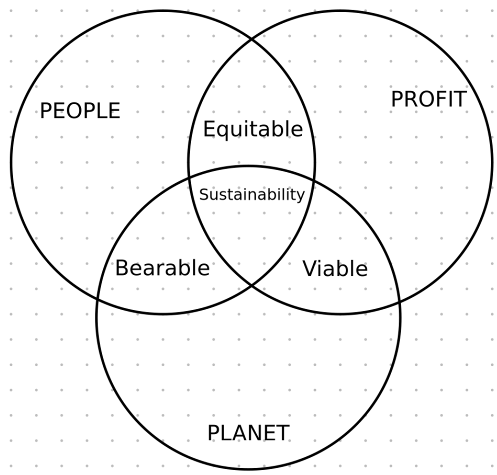

Figure 1: Triple Bottom Line Graphic

1.2.2 Life Cycle Assessment

This is a way to determine the impact of a certain device over its life cycle from when it is created in the factory (or before), to when it goes into the landfill (or potentially after). We analyze the inputs, outputs, and potential environmental impacts of the product over its lifetime.

We start by determining the frame of the LCA analysis, we can either do:

- Cradle to Grave - From raw materials to end of life
- Cradle to Gate - From raw materials to gate of manufacturing facility (before transportation to consumer)
- Cradle to Cradle - From raw materials, to end of life, and then it is recycled into new raw materials

We have a bunch of stages in the LCA analysis such as:

- Raw materials acquisition
- Materials manufacture
- Product manufacture
- Product use / Consumption
- Disposing of product (recycling, or dump)

1.2.3 Normalization

This is a way to calculate greenhouse gas emissions using a standard metric. This allows us to fairly compare products to other products to see which products create the least emissions.

1.3 Manufacturability

This is about designing products that can efficiently (and actually) be manufactured. We have to know actually how to make each part of the product, such as what machine will make the part, and how it will be made.

We need to make some sort of sketch of the product and its parts with dimensions such as a CAD model.

A few points to keep in mind when designing for manufacturability are:

- Avoid customization to make the process easier, use already existing products if possible.
- Reduce the number of components as much as possible
- Use processes that are faster for prototyping
- Select the correct tool for the job

Below is a bunch of tools with what they **should**, and **should not** be used for:

Table 1: 3D Printer

YES	**NO**
• Complex geometries	• Flat Items
• Minimal Supports	• Threads
• Small Parts	• Weight Bearing parts
• Brackets and Adapters	• Waterproof parts

Table 2: Laser Cutter

YES	**NO**
• Flat cuts	• Round Materials
• Enclosures	• Structural Parts
• Templates	• Parts that need to be screwed into
	• Thick materials

Table 3: Arduino

YES	NO
• Low power low voltage circuits	• High power circuits • Circuits that don't need code, only power

Table 4: Drill Press

YES	NO
• Circular Straight holes	• Precise hole position • Not all the way through a hole • Large holes, or Square holes

Table 5: Mill

YES	NO
• Metals and Plastics • Slots and Holes • Holes not all the way through • Flat sides • Precise Machining	• Circular Geometry • Don't use wood • Sharp Inner corners

Table 6: Lathe

YES	NO
• Coaxial Geometry	• Square Parts • Long parts • Don't use wood or 3D printed parts

1.4 Ethics

Ethics are the duty of us (the engineer) to society as a whole.

We definitely want to do good work, and maximize benefits and minimize harm. We also want to respect people, and treat them fairly. We do this by using a lot of different ethical lenses.

These are ways of thinking to guide us to evaluate a decision from different perspectives.

We have four lenses:

1. Utilitarian
2. Rights
3. Common Good
4. Virtues
5. Equity

1.4.1 Utilitarian

For the utilitarian lens, we need to consider the overall happiness or welfare the action will bring about.

We could say that minimizing costs of a product would increase overall happiness since more people could benefit from the product.

We could also say that having good customer service would increase overall happiness.

1.4.2 Rights

For the rights lens, we want to ensure that people's rights are upheld. This includes but is not limited to:

- Right to life
- Right to liberty
- Right to privacy

We could say that reducing the environmental impact of a product would uphold the rights of future generations to a clean environment.

We could say that having good data protection measures in software upholds the users rights to privacy.

1.4.3 Common Good

The common good lens is about emphasizing the well being of a community as a whole such as having an accessible health care system, having world peace, and having a just legal system.

We could say that designing for accessibility would be for the common good since it benefits the community as a whole.

1.4.4 Virtues

A virtue is a character trait that is considered to be morally good. It is a behavior that is right, and avoids being wrong.

Virtue ethics asks the question of "Who do I want to be? What choices do I want to make?".

We could say that adding accurate and not misleading product descriptions would be good from the virtue lens because it is showing the character trait of honesty.

We could also say that designing for accessibility is good in the virtue lens since we are showing the character trait of fairness.

1.4.5 Equity

Equity means that everyone gets their due. It does not mean that everyone is equal, but everyone gets what they need to be successful. For example, someone who is poor might get a lot of government assistance and food, while someone who is rich would not get any of that extra help since they are already doing well.

The equity lens is about ensuring the appropriate distribution of benefits and burdens.

We could say that adding a discount for low income families would be good in the equity lens since it helps give a better distribution of benefits.

We could also say that fair labour practices are good in the equity lens since it gives the correct and fair benefits to workers.

2 Concept Development Process

We have a few different design processes such as:

- Waterfall - Sequential process
- Agile - Iteratively create a prototype, get feedback, then find solution, and repeat
- Spiral - Similar to agile method with different prototypes solving iterative problems, but we add risk analysis
- Co-Evolution - Represents evolution of problem space, and solution space, the problem and solution evolve together, useful for ill defined problems
- Iterative - build → test → refine → repeat

For all of the design methods, to manage the project we have 4 main points:

- Plan - Is the plan well laid out
- Processes - Are the processes well defined
- People - Do we have a good team

- Power - Distribution of authority

We can use a GANTT chart to manage the project, this breaks up the project up into multiple sub-tasks, with estimated completion times, and dependencies identified.

For the Iterative Engineering Design Process (IEDP), we first generate solutions, then check if these solutions satisfy the DFX. If so, we prototype and see if the solution works, if it does not, we go back to the start (generate solutions).

When coming up with the solutions, we need to generate a large amount of them. First we remove all concepts that are not feasible (do not meet needs, or are physically impossible). Then we score these solutions using a decision matrix that contains different factors. Finally we test.

Criteria	**Weight**	**Car A**	**Car B**
Cost	0.5	8	3
Reliability	0.4	3	10
Features	0.1	4	6
Total	1	4+0.4+1.2=5.6	1.5+4+0.6=6.1

Table 7: Decision Matrix Example

2.1 Bias and Concept Generation

We have a lot of cognitive biasses that can affect our decision process. We need to be aware of these biasses.

- Anchoring Bias - Relying on first piece of information
- Blind Spot Bias - Failing to recognize bias in yourself
- Confirmation bias - Only trusting information that confirms my beliefs
- Negativity bias - Only focusing on negative events
- Outcome bias - Only judging based on outcome

We can try to overcome this bias by using concept generation (creative thinking) strategies.

- Sketching
- Lateral Thinking - Thinking outside the box

  How would we deal with this in a different time period?

  How would we deal with it in a different country?

  How would we deal with it as a different gender or age?

  How would we deal with it as someone else?

- Evolution - Find and review existing products
- Synthesis - Combine two products into one
- SCAMPER - Substitute Combine Adapt Modify Put to another use Eliminate Reverse
- Morphological Analysis -

  Identify Problem and Separate Variables

  List many variations for each variable

  Randomly select lots of variations

  Find a good variation to make a whole

3 Prototyping, Testing, and Iteration

A prototype is an early model of a product built to test a concept or process in order to learn something for the final product.

Since the prototype tests **a** concept, we almost always need more than one prototype to test multiple concepts.

We have different levels of prototype fidelity, we can have a low quality low fidelity prototype, medium fidelity, or high fidelity. We also need to come up with a plan to test this prototype.

When coming up with a prototype plan, we need:

- Prototype Purpose
- Prototype Fidelity
- Built Plan
- Test Plan

Note that these prototypes and tests do not have to be physical, they can be done in software and/or using calculations.

4 Teamwork

Productivity is maximized when the task requirements, team dynamics, and individual situations align well. In practice, this is very hard to achieve.

Throughout a project, a team has a bunch of stages that it will go through:

1. Forming - Start of team, introductions
2. Storming - Team conflict and problems
3. Norming - Reconciling the conflict

4. Performing - Doing the project well
5. Adjourning - Wrapping up the project

To determine how well a team is working together, we use the CARE model:

- Communicate - How well the team shares information, and manages conflict, are roles well defined
- Adapt - How well the team manages changing conditions
- Relate - How well the team trusts each other to get the work done, and other interpersonal factors
- Educate - How well the team learns, reflects, and evolves

One of the major factors we can see here, is how well the team manages conflict. So we need to know of ways that are used to manage this conflict, and come to a solution that is acceptable for everyone on the team.

Something to note is that not all conflict is bad, some is either good, or will resolve itself. Some conflict will promote better solutions, but it needs to be kept at a reasonable level. However, both sides need to be thinking rationally, not emotionally (want to find the best solution, not want to win).

- Dominating
- Integrating (Collaborating)
- Accommodating
- Avoiding
- Compromising

5 Intellectual Property

Intellectual Property is any knowledge or expression created using the brain. We need to know about different ways to protect this IP.

The way we protect it depends on the medium of the knowledge.

	Patents	**Copyrights**	**Trademarks**
Term	Up to 20 years	50 or 70 years	10 years, renewable
What is protected	Useful, non-obvious inventions	Art, software, websites, etc.	Designs, shapes, logos, etc.

6 Economics

6.1 Cost Classifications

When running a business, we can classify costs as either **variable** or **fixed** (or **semi variable**). Then we can also classify them as **direct** or **indirect**.

Indirect vs Direct is whether it directly relates to a specific project or not. If it does relate to a specific project, then it is a direct cost. Otherwise, it is an indirect cost.

Variable vs Fixed is whether the cost scales with output or not. For example, the cost of gas for heating a factory is the same whether we are making 1 item a day, or 1000 items per day. However the cost of materials for 1 item is a lot cheaper than 1000 items.

6.2 Fundamental Concepts

We have two main types of economics. **Macroeconomics** deals with a national economy, and everything within a country. **Microeconomics** deals with *one* person, group, or company. We just focus on this one entities economics.

Money is not static with respect to time, it has a time value. A certain amount of money now is worth less in a year because of **interest**. We have compound interest, or simple interest. They can be calculated as follows:

$$\text{Simple: } (1 + i \cdot a) \cdot C_0$$
$$\text{Compound: } C_0 \cdot \left(1 + \frac{i}{n}\right)^{n\times a}$$

where C_0 is the principle amount, i is the annual interest rate, a is the number of years, and n is the number of interest periods/payments per year.

Due to interest, we can calculate the **Net Present Value (NPV)** of money at a certain time. This is useful since it allows us to account for time when comparing different income opportunities. For example, getting paid 100$ now, or 110$ in 6 months. We can evaluate which one is worth more right now by accounting for the interest we would make on the 100$ over 6 months.

$$PV = \sum \frac{FV}{(1 + \frac{i}{n})^{n\times a}} \qquad \text{OR} \qquad FV = \sum PV(1+i)^n$$

where PV is the present value, FV is the future value, and the denominator is just the interest calculation.

Depreciation means that new things are worth more than old things. This is especially true with large machines used in business. We use the **straight line depreciation** equation to calculate the cost of an equipment over time.

$$D_L = \frac{\text{Equipment Cost}}{\text{Useful Life}}$$

6.3 Economic Decision Making

To make economic decisions, we have a few different ways.

- Break Even Analysis
- Sensitivity Analysis
- Return on Investment (ROI) and Simple Payback Period
- Cost/Benefit Trade-off Analysis

If we are deciding on whether or not to make or buy a certain product, often the cost to make the product will be less for large quantities of the project, but more for just one product. For example, repairing a mobile phone vs paying someone to do so. If I repair a phone, I need to buy a few hundred dollars of equipment and then I can do the repair for cheap. If I pay someone, I might only pay them 100$ though. If I repair 10 phones, it would be either 1000$, or if I do it myself, a few hundred in equipment and then small material fees.

Break even analysis is the point at which the cost to buy equals the cost to make, or the cost to produce equals the revenue. This is a number. Going to the phone example, if we spend 300$ on tools, and 50$ per phone if I do it, vs 100$ if a shop does it, then at 6 phones, if I do it I spend 600$, vs the shop charges 600$. We consider the break even point 6 phones.

Sensitivity analysis allows us to see the profitability of a certain project in different situations based on varying different variables. So we could say "What if we spend 20% more on development?" or "What if we take an extra week to deploy?" or "What if we sell it for 2$ cheaper?". We could see the impact on the profit for each of these situations.

Return on Investment (ROI) is calculated using:

$$ROI = \frac{\text{Net Profit}}{\text{Value of Investment}} \times 100\%$$

Note that we need to account for the time value of money in this calculation.

The **simple payback period** is the amount of time it takes to recover the initial investment. This does not take into account the time value of money.

$$n_{tot} = \frac{\text{Value of Investment}}{\text{Net profit per period}}$$

Cost/benefit trade off analysis sows is the advantages and disadvantages on both sides.

$$BCR \text{ (Benefit Cost Ratio)} = \frac{\text{PV of Benefits}}{\text{PV of Costs}}$$

6.4 Financial Statements

There are three types of financial statements:

- Balance Sheets (Snapshot of the financial condition at a *certain time*)
- Cash flow statement (Cash in and Cash out over a *period of time*)
- Income Statement (Changes in wealth over a *period of time*)

For the **balance sheet**, we just show the equity which is just the assets - liabilities. Assets include current assets, cash, inventory, long term assets, and depreciation (negative asset). The liabilities are accounts payable, and borrowing. The net worth is the equity (assets - liabilities).

The **cash flow statement** shows the cash in (operations, sales, tax received, borrowing, investments) and the cash out (spending, operation expenditures, bill payments, tax out, asset purchasing, debt paying). We get the net cash flow which is the cash in - cash out.

The **income statement** (profit/loss statement) shows the sales, and expenses to get the profit/loss. We take the sales, and subtract the cost of goods sold and operating expenses. This is the **operating income** (Earnings Before Interest [EBI]). Then once we factor in all interest (a cost to what we are borrowing) we can get the **Earnings Before Taxes (EBT)**. The **Net Income** taxes into account income tax.

7 Appendix