Pearson BTEC Levels 4 Higher Nationals in Engineering (RQF)

Unit 1: Engineering Design

Unit Workbook

Engineering Design

Purpose The purpose of this unit is to understand the design process in engineering, and consider the thought process that is involved for such a task. This involves listening to the clients, and developing their ideas to produce the product they want. **This workbook is to be read with the eBook, and will cover the gaps in the Learning Objectives that the eBook does not cover**. The chapters that should be read, if you wish to study from the eBook, are Chapters $1-12$, and Appendix B. Chapters 13 and 14, and Appendix A, are more directed towards manufacturing engineers, Chapters $15-17$ would be useful when studying Unit 4: Managing a Professional Engineering Project.

1. Learning Objective 1

1.1 Industry Measurement Standards

Purpose When it comes to designing, it is important that everyone is aware of the measurements, the global standard of measurements is based on the International System of Units (SI units). The seven base units shown in Table 1.1, along with their typical notations in equations. By not having a global standard, it becomes incredibly difficult to collaborate; two notable examples were the times before Europe adopted the Gregorian calendar around the 1700s, armies from allied nations would be late to reinforce because they had the wrong dates; another, more modern example, was the £100 million Martian satellite that crashed because one part of the code calculated Force in pounds, while another part calculated using Newtons.

Table 1.1: The seven base units used by SI

Unit	Measures	Equation Notations
Ampere (A)	Electrical current	I
Candela (cd)	Light intensity	I_v
Kelvin (K)	Thermodynamic Temperature	T
Kilogram (kg)	Mass	m
Metre (m)	Distance	s or d
Mole (mol)	Amount of a substance	n
Second (s)	Time	t

With these we can develop more SI units for the wide range of measurements that are taken throughout the world, some of examples of this can be seen in Table 1.2.

Table 1.2: Equations used to develop the SI unit catalogue

Measurement	Equation	Unit Equation	Unit of Measurement
Velocity	$v=\frac{ds}{dt}$	$\frac{m}{s}$	ms^{-1}
Acceleration	$a=\frac{dv}{dt}$	$\frac{ms^{-1}}{s}$	ms^{-2}
Force	$F=m\cdot a$	$kg\cdot ms^{-2}$	N (Newtons)
Work	$W=F\cdot d$	$N\cdot m=kgm^2s^{-2}$	J (Joules)

The use of SI units makes it much easier to collaborate, but sometimes numbers can be too large or too small. For example, the distance between Earth and Mars is 54.6 million kilometers or $54{,}600{,}000{,}000\ m$, which is a difficult number to read, and long to write out every time the number needs to be mentioned. Another example of this is Avogadro's constant, the number of atoms in one mole of a substance, is $602{,}214{,}085{,}700{,}000{,}000{,}000{,}000$. With this in mind, we can add a prefix to the unit, and also convert to the "standard form", explained better in Table 1.3.

Table 1.3: Converting numbers to easier to read forms

Number	Prefix	Symbol	Standard Form
1,000,000,000,000,000	Peta-	P	10^{15}
1,000,000,000,000	Tera-	T	10^{12}
1,000,000,000	Giga-	G	10^{9}
1,000,000	Mega-	M	10^{6}
1,000	Kilo-	k	10^{3}
0.001	milli-	m	10^{-3}
0.000001	micro-	μ	10^{-6}
0.000000001	nano-	n	10^{-9}
0.000000000001	pico-	p	10^{12}
0.000000000000001	femto-	f	10^{-15}

So, we can say Avogadro's constant is $6.02 \cdot 10^{23}$. We can also mix the symbols and standard form, it is rare when talking about distances to go above kilometers, so the distance to Mars would typically be written as $54 \cdot 10^{6} km$. The likes of Mega and Giga are used when discussing material properties, while Tera and Peta are used in conjunction with analysing the likes of the national grid, and the power plant outputs. While the likes of milli, micro, nano, pico and femto are used in physics and biology. The HIV-1 virus weighs about $1fg$, and a proton has a diameter of about $1.6fm$.

1.2 Industry Health Standards

Purpose

It is also important to adhere to industry standards when concerned with health and safety, certain health practices and codes must be considered. For example, every workplace should complete a risk assessment every year, which can also consist of separate forms such as the Control of Substances Hazardous to Health (COSHH) and manual handling. More information on this can be found on the government website, linked below.

http://www.hse.gov.uk/

1.3 Organising the Design Process

Purpose

Without appropriate discipline and planning, the design process will just implode and fail. The design team will need a leader to help keep them on track, and it can also help to have a secretary to record the minutes and perform any administrative duties.

Time management can be the downfall to most projects, failure to keep track of time can cause the deadlines to overshoot and this can also increase expenditure. There are several methods of timekeeping, one of the most famous is the Gantt chart. This will show the project breakdown with the start and end dates and their respective time allocation. Most Gantt charts will map day by day, however, depending on the length of the project it can turn to weeks.

3	Literature feedback and produce specification	15/02/18	16/02/18	2 days	2
4	Design generation	19/02/18	23/02/18	5 days	3
5	Procure tools	26/02/18	02/03/18	5 days	4
6	Procure materials	26/02/18	02/03/18	5 days	4
7	Complete risk assessments to workshops	26/02/18	02/03/18	5 days	4
8	Product manufacturing	05/03/18	09/03/18	5 days	5;6;7
9	Product testing	12/03/18	13/03/18	2 days	8
10	Design refinement	14/03/18	16/03/18	3 days	9
11	Produce presentation	19/03/18	21/03/18	3 days	10;13
12	Rehearse presentation	22/03/18	30/03/18	7 days	11
13	Produce project report	15/02/18	16/03/18	21 days	

With Table 1.4 produced, we can now translate it across to project management software, such as ProjectLibre, which is open source and free to download. Fig.1.1 below shows the Gantt chart of such a project. The Gantt chart assumes that the team take the weekends off. The arrows that you can see are used to show that the task is required to start the next task.

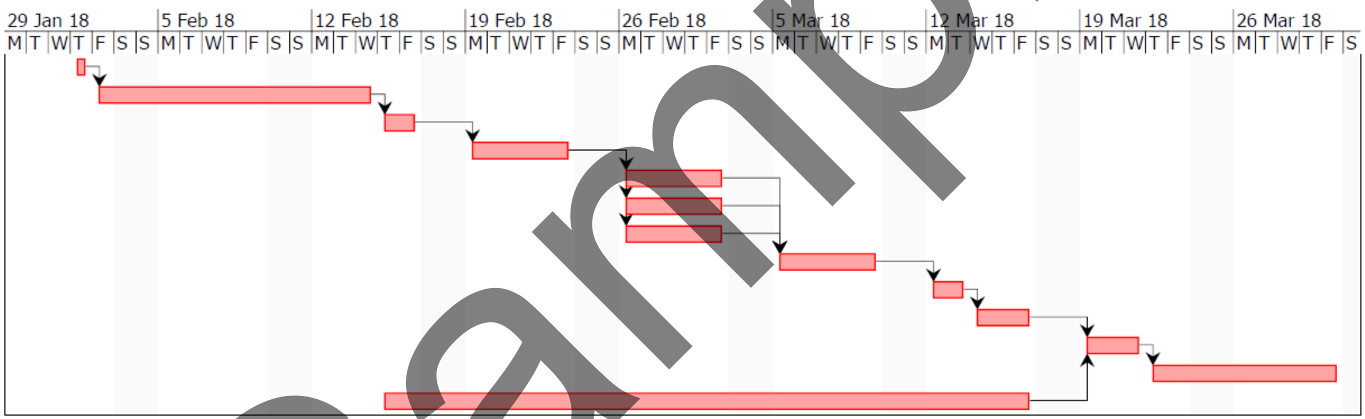

Fig.1.1: Gantt chart for a two-month design project

Going back to the original point of finding the critical path, since this has been a very linear design project, and its clear that the critical path is simply:

$$1 \rightarrow 2 \rightarrow 3 \rightarrow 4 \rightarrow 5 \text{ (or 6 or 7)} \rightarrow 8 \rightarrow 9 \rightarrow 10 \rightarrow 11 \rightarrow 12$$

Some projects can be much larger and more scattered with their critical path.

1.5 Five-Stage Design Process

Theory

The design stage is built around a seven-stage process developed by Herbert Simon in 1969. There are many variants to this, ranging from three to seven stages, but are based on the same principles by Simon.

For this unit, we will focus on five-stage design, the five stages are:

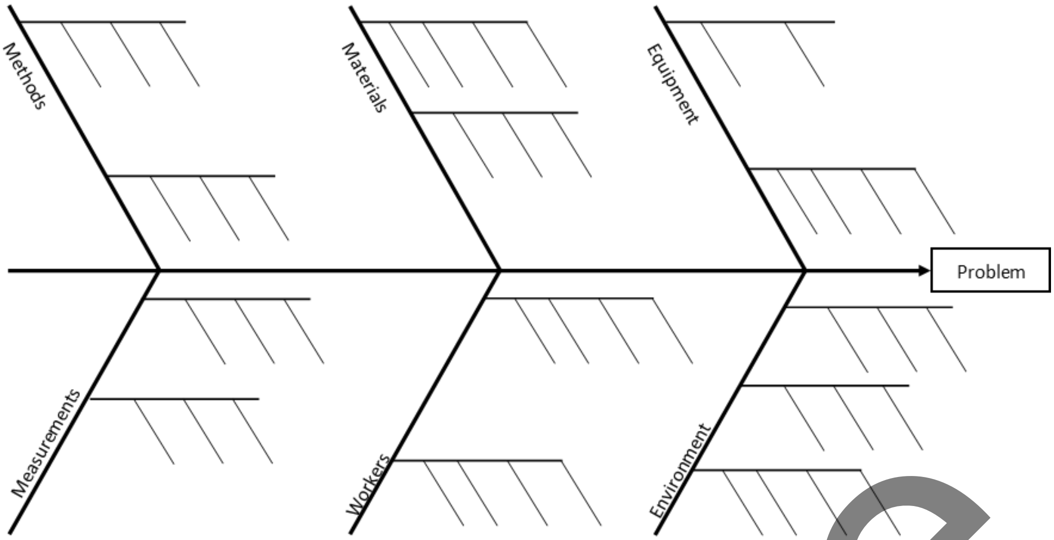

Fig.2.1: A cause and effect diagram template

3. Learning Objective 3

The material for Learning Objective 3 is covered by the eBook

4. Learning Objective 4

4.1 Presentation Tools

Purpose

A slideshow is important when presenting your design, they should convey only the essential information, and be kept short and sweet. They should have a simple and professional manner to them, not getting carried away with any animations or slide transitions.

Theory

The most powerful tool in a presentation, however, is you; when people buy your product, they are also buying you. The audience is most likely going to spend most of their time looking at you, so it's important that you are also well presented, and dressed for the occasion. The audience also reads your body language, and its small things such as "crossing your arms" makes you look confrontational and closed off, or slouching can show a lack of confidence, which is conveyed into a lack of confidence in your design, this can also be displayed by a monotonous tone or having your hands in your pockets. For anyone who lacks confidence, its easy to fake just by rehearsing the presentation, once you have got into the routine, it becomes well versed and you will come across as more confident.

A demonstration of the design is also welcome, whether this is a physical demonstration in the room, or a video if the design is not suited for a board room.

4.2 Analysis of Presentation Feedback

There will always be feedback from the presentation, no one is perfect, the most important thing about feedback is to take it on board, never dismiss it, and use it to grow and develop either the product or yourself. If we think about the five-stage design process discussed earlier we could say the presentation is the prototype or test phase, which will feed back into the empathise, problem or idea stages.