Name:

International SCHOOL OF LONDON Qatar

DP DESIGN TECHNOLOGY

TOPIC 3

MODELLING

NOTES & GUIDANCE BOOKLET

2022 - 2023

This booklet contains the Notes, and teaching support material for Topic 3

DP DESIGN WITH

MR MONEEB

Contents Page

Teaching & Learning Presentations

Topic 3: Checklist

CORE TOPICS		Topic Covers	Approx Lessons hours on each topic	Total Lesson Hours	Checklist (✓)	Exam Mark	Exam (%)
3	Modelling	3.1. Conceptual modelling	2	10			
		3.2. Graphical modelling	2				
		3.3. Physical modelling	2				
		3.4. Computer-aided design (CAD)	2				
		3.5. Rapid prototyping	2				

3.1 Conceptual Modelling

Essential Idea:

A conceptual model originates in the mind and its primary purpose is to outline the **principles**, **processes** and **basic functions** of a design or system.

Concepts and principles:

- The role of conceptual modelling in design
- Conceptual modelling tools and skills

Essential Understanding:

- How conceptual models are used to communicate with oneself and others
- How conceptual models vary in relation to the context
- How the designer visualizes concepts, design thinking and learning
- Advantages and disadvantages of using conceptual modelling

You as a designer:

Designers use conceptual modelling to assist their understanding by simulating the subject matter they represent. Designers should consider systems, services and products in relation to what they should do, how they should behave, what they look like and whether they will be understood by the users in the manner intended.

Topic 3.1: Conceptual Modelling

Notes / Activities

The Role of Conceptual Modelling in Design

A model that exists in the mind used to help us know and understand ideas.

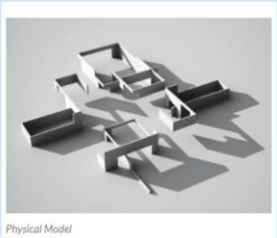
Conceptual models are:

- a model of concepts or ideas (abstract) that exist in the mind.
- used to help us know and understand, design thinking, ideas, casual relationships, principles, data, systems, algorithms or processes.
- used to illustrate relationships that is in the designers mind to others.
- able to help explain the thinking behind new ideas.
- able to help us to communicate with other members of design team, manufacturer or client.
- able to help us visualise ideas through graphic, physical and virtual models.

Conceptual Modelling Tools and Skills

Graphical Model
A visualization of an idea, often created on paper or through software, in two or three dimensions.

Physical Model
The creation of a smaller or larger tangible version of an object that can be physically interacted with.



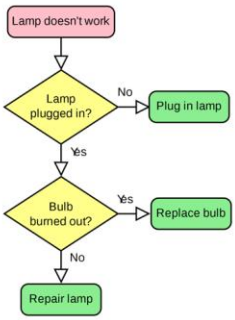
Virtual Model
Photorealistic CAD-based interactive models that use surface and solid modelling. They can be considered 'digital mock-ups'.

Computer-Aided Design: generated virtually

The the designer visualizes concepts, design thinking and learning with:

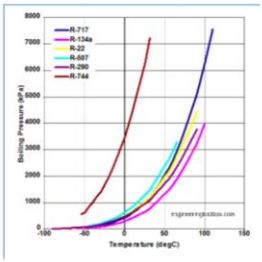
- Graphical models such as flow charts, drawings and diagrams.
- Physical Models with clay, card, 3D printing, foam or wood (easily worked wood like Balsa).
- Virtual Models using CAD, simulation and other software.

Graphical model



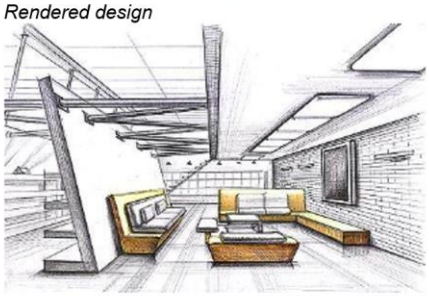
A flow chart

Design cycle diagram



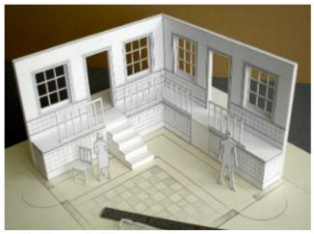
A graph

Rendered design



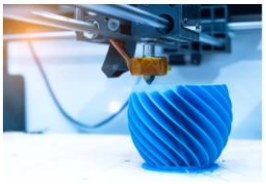
Interior drawing perspective

Physical model



Card modelling

Clay modelling



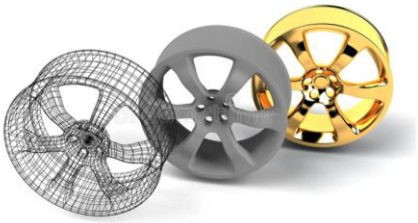
Right - 3D printing
Left- Balsa architectural modelling

Foam modelling

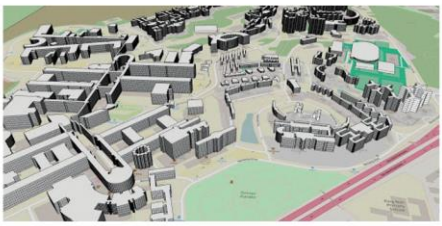
Virtual model

Virtual modelling

Virtual humans



Different rendering techniques

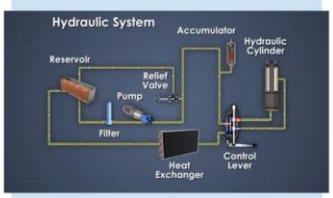


Virtual environment

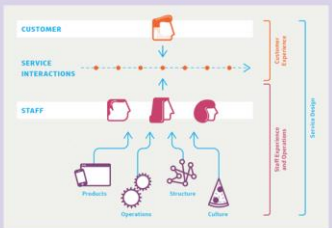
Conceptual Models Vary in Relation to the Context

The design context could be systems, service or product design:

Systems design
is the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements.



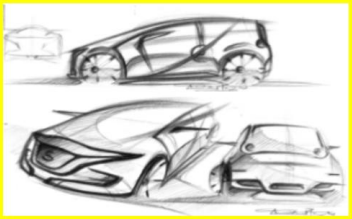
Service design
is a form of conceptual design which involves the activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customer.

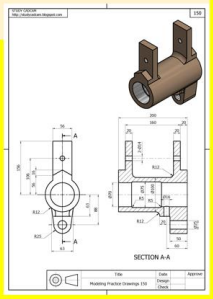


Product design
The process of generating ideas and then developing them into a final product to be sold to consumers.

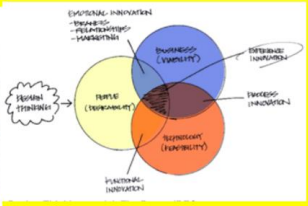
Notes / Activities

Activity: Which modelling technique would most likely be used in each of the design contexts?







Advantages and disadvantages of conceptual modelling

Advantages

- *Shares 'Big Picture'*
- *Makes it easy for non-designers and non-technical people to understand a complex idea*
- *Communication with clients and users*
- *Communications with team members*
- *Ability to manipulate ideas better that with drawings alone*
- *Helps establish proportion*
- *Gauge people's reaction to concept or idea*

Disadvantages

- *Lacks detail*
- *Can be misinterpreted*
- *Scale models can be misleading when the product is smaller or larger*
- *Materials may not reflect the final choice of materials- difficult to emulate*
- *Simplicity of model can lead to vital aspects of a concept being left out*

Guiding questions

1. *What are the 3 main types of concept models?*
2. *The I.B. design cycle is an example of what type of concept model?*
3. *How do designers choose the appropriate concept model?*
4. *Why are concept models useful?*

Notes / Activities

Topic 3.2: Graphical Modelling

Essential Idea:
Graphical models are used to communicate design ideas.

Concepts and principles:

- 2D and 3D graphical models
- Perspective, projection and scale drawings
- Sketching versus formal drawing techniques
- Part and assembly drawings

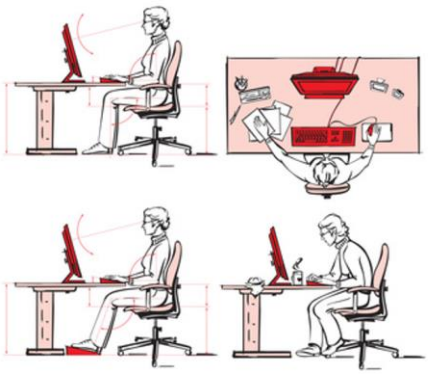
Essential understanding:

- How graphical models are used to communicate with oneself and others
- How the choice of graphical models varies in relation to the context
- Advantages and disadvantages of using different graphical models

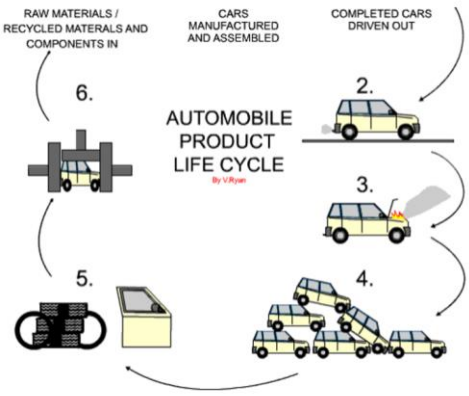
Nature of design:

Graphical models can take many forms, but their prime function is always the same—to simplify the data and present it in such a way that understanding of what is being presented aids further development or discussion. Designers utilize graphical modelling as a tool to explore creative solutions and refine ideas from the technically impossible to the technically possible, widening the constraints of what is feasible.

2D Graphical Models



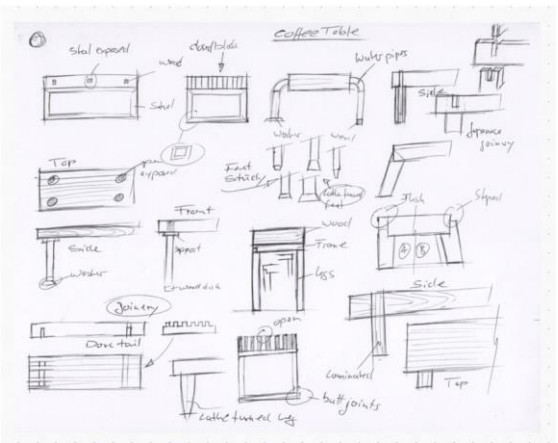
Diagram



Pictorial Flow Chart

2D Graphical Models

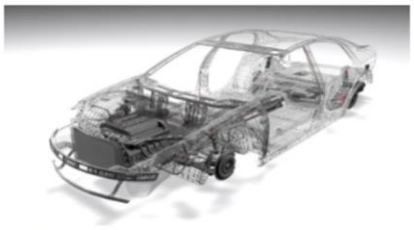
Rendered Sketch



Concept Sketches

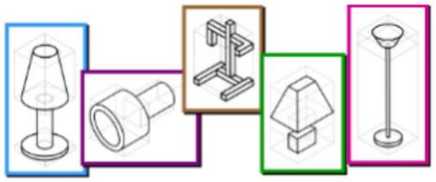
Notes / Activities

3D Graphical Models



CAD Model

Perspective Drawing



Isometric

Perspective, Projection and Scale drawings

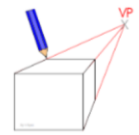
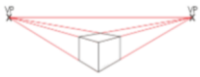
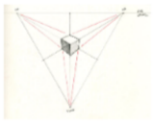
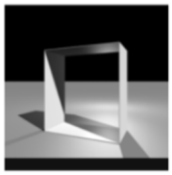
Perspective: *A set of formal drawing techniques that depicts an object as getting smaller and closer together the further away they are. The techniques are one-point perspective, two-point perspective, and three-point perspective.*

A 3D drawing that realistically represents an object by utilizing foreshortening and vanishing points (usually imaginary ones).

Perspective drawings take into account spatial arrangements, for example.

Can be used in the planning stages to communicate what it might look like.

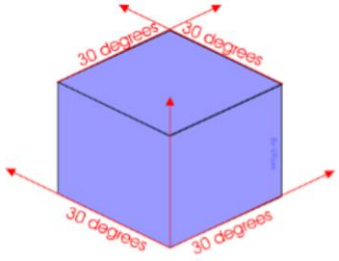
Good for clients who may not understand orthographic or isometric drawings.

One Point	Two Point	Three Point
		
 Image from ArtFactory.com	 Image from ArtFactory.com	 Image from ArtFactory.com

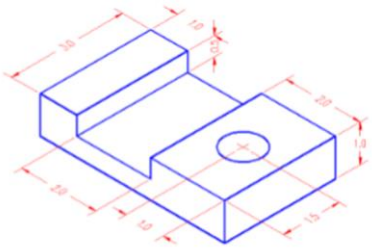
Perspective, Projection and Scale drawings

Isometric Drawing/Projection

Projection Drawings – Systems of drawings that are accurately drawn, the two main types are isometric projection (formal drawing technique) and orthographic projection (working drawing technique).
An isometric drawing depicts the proposed solution in 3D showing shape and form. They are drawn on a 30/90/30 degree axis.



Isometric Axes – image from technologystudent



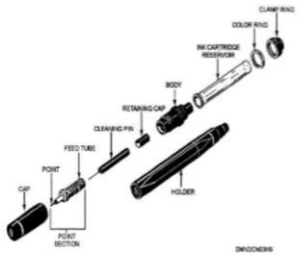
Isometric Drawing with dimensions

Notes / Activities

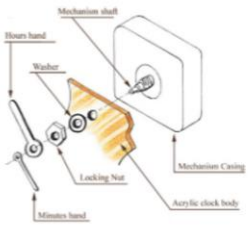
Perspective, Projection and Scale drawings

Exploded Isometric Drawing

An isometric drawing of an object with more than one component that depicts how the parts of assemblies fit together.
The drawing is exploded to show component parts of a product and/or the sequence of assembly.
Isometric drawings are produced at the final solution stage and are used as working drawings in the realization stage.



Exploded Isometric of a Pen



Clock Mechanism

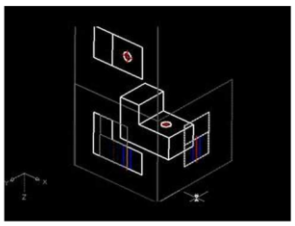
Perspective, Projection and Scale drawings

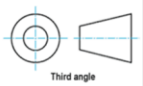
Orthographic Drawing/Projection

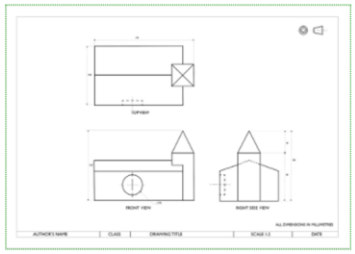
A series of flat (2D) views of an object showing it exactly as it is in shape and size i.e. constructional details. An **orthographic** drawing shows all details and dimensions and is usually used as a production/working drawing. **Orthographic drawings** are produced at the final solution stage and are used as working drawings in the realization stage.

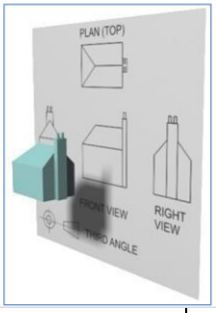
3rd Angle Projection

International conventions need to be used, such as, 3rd Angle projection, ISO, scale, units, etc which will be explained in criterion C.


Orthographic Drawings

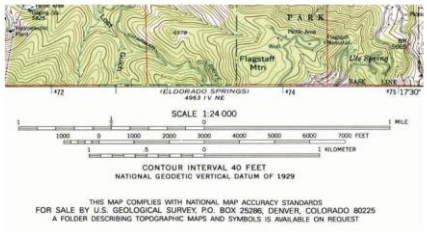


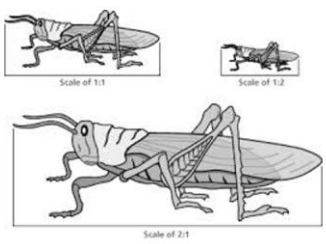

Orthogonal Drawing



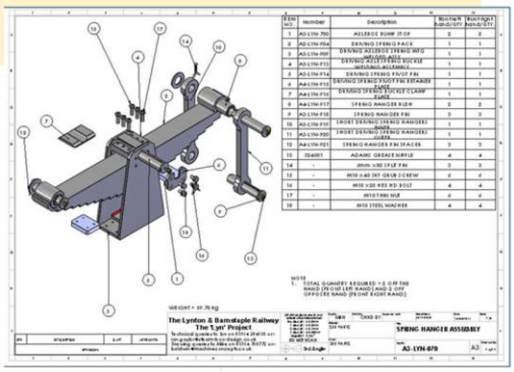
Perspective, Projection and Scale drawings

Scale Drawings – *Drawings that are bigger or smaller than the real product, but exactly in proportion with product.*
Maps were some of the early drawings that we scaled. By 'mapping' landscapes early explorers were able to record the land and sea and make scaled drawing or maps.
Topographically maps have large scales i.e. - 1:24 000 because the area they represent are huge.
Architects use decreasing scales of 1:100, 1:50 to be able to represent the building in a large enough piece of paper or model.
Enlarge scales of 2:1 could also be used for detail work where the dimensions are too small to be represented at 1:1.



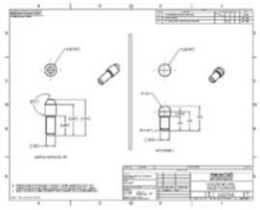


Assembly and Parts Drawing



Assembly Drawing – *A diagram that shows how components fit together to make a whole.drawings Typically presented in an exploded view. Assembly drawings show how different parts [components] go together, identify those parts by number, and have a parts list, often referred to as a bill of materials.*

Parts (Component) Drawing – *Orthographic drawings of the components of an assembly containing details just about that component*

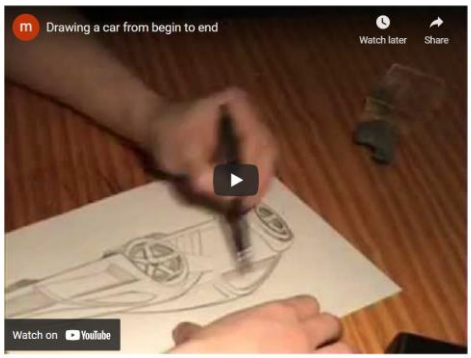


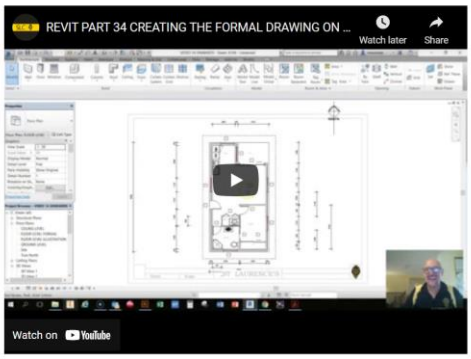
Part/Component Drawing

Sketching versus Formal Drawing Techniques

Sketches – *Rough drawings of ideas used to convey or refine the idea.*

Formal drawing techniques – *A type of drawing technique that has fixed rules, the most widely used being isometric projection and perspective drawing*





Sketching versus Formal Drawing Techniques

Sketching or freehand drawings

- *Are spontaneous representation of ideas on paper without the use of technical aids.*
- *Designers use a range of freehand drawings in the early stages of developing ideas to explore shape and form (3D) and constructional details (2D).*
- *Divergent thinking is prominent at this stage.*

Formal drawings

- *Include: orthographic, isometric, exploded isometric, sectional, parts and assembly drawings which are done with great precision and usually with mechanical drawing aides (ruler, square, compass) or in CAD programs (Autodesk Fusion).*
- *Designers use these drawings at the realisation/development stage where the product is to be made. They are used to communicate to the manufacturer.*
- *Convergent thinking is prominent at this stage.*

Annotations

- *Explain the thinking behind the visual image represented by the drawing.*
- *They allow the designer to consider the implications of the ideas for further development.*
- *Annotated drawings are an alternative form of expression of ideas that allows one to indicate links between the ideas.*

Notes / Activities

Advantages and Disadvantages

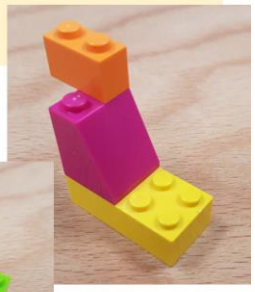
Advantages	*Disadvantages*
2D and 3D Freehand Sketching , Perspective • Quick visual image to generate and develop ideas, • Used to convey ideas to clients or consumers • Explain thinking behind the visual image • Promotes creativity	2D and 3D freehand sketching, Perspective • Cannot manipulate/ handle/ change them • Rely on the ability of viewer to interpret the model – not the case with a physical model
Formal drawing • Shows in detail sizes of concept • Can be used to construct • Accurate • Different views of object shown that couldn't see from a 3D drawing	Formal drawing • Time consuming • Requires high level of skill • Specialist equipment needed • Technical drawings can be difficult to understand by a non- technical audience
Assembly drawings • Can show how the product is assembled – show how it works	Assembly drawings • Time consuming • Specialised knowledge and skills required

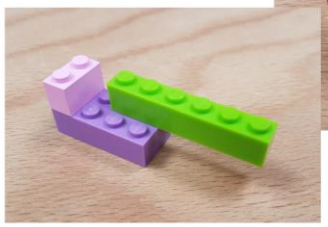
Task

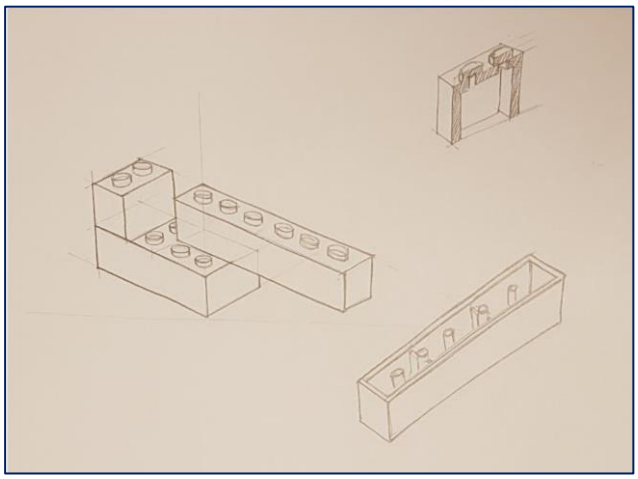
Choose 3 different lego pieces and stack them as you wish.

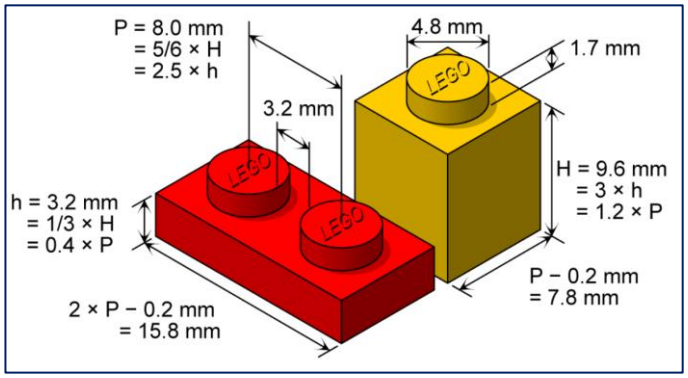
Represent the object created it using

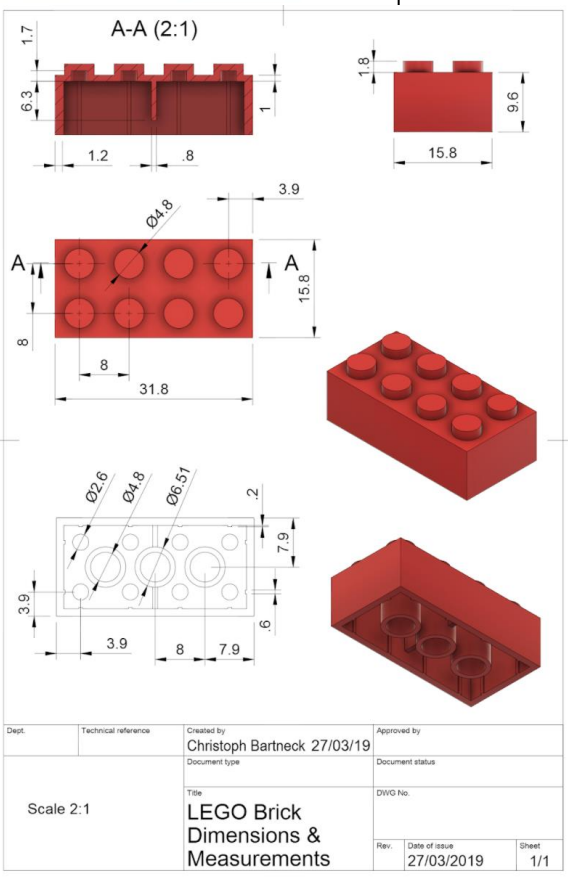
- freehand sketch
- isometric projection
- Fusion - exploded isometric projection
- Fusion - orthographic projection at scale 1.1 (top, front, side and bottom views + a section view)
- Zoom in detail at scale 2.1











Notes / Activities

Guiding questions

1. Why are graphical models used?
2. At what stage of the design process are freehand sketches used?
3. What angles are used in isometric drawings?
4. What is a limitation of the isometric drawing technique?
5. How can the limitations of drawing in isometric be overcome?
6. Why are orthographic projections used?
7. Give examples of when a smaller scale and a larger scale might be used
8. At what stage of the design process are formal drawings used?
9. Why are assembly drawings useful?
10. What type of model is the I.B. Design cycle?
11. What type of graphical model would be used to communicate the design of an airport interior
12. When might foreshortening be apparent?

Exam style questions

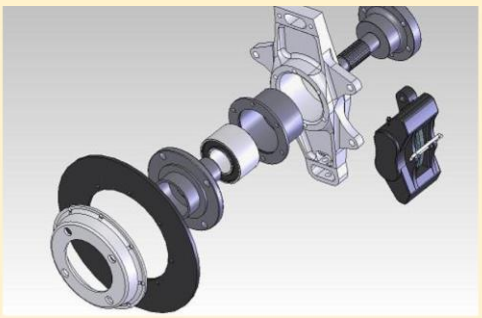
1. Which drawing technique is most useful to the manufacturer?

A. Freehand
B. Perspective
C. Orthographic
D. Isometric

2. What is an advantage to a designer of using a perspective drawing?

A. It can be used as a working drawing for manufacturing.
B. It is easy to construct the drawing with the use of a set square.
C. It is good for communication with clients.
D. It is easy to use with CAD.

3. What type of drawing is shown below?



A. Perspective
B. Exploded isometric
C. Orthographic
D. Isometric

4. Which type of drawing would be **most** suitable to show the public a proposed new design for the interior of an airport building?

A. Orthographic
B. Isometric
C. Exploded isometric
D. Perspective

5. Why is annotation of freehand drawings important to aid design development?

A. They describe the drawing
B. They label the parts of the drawing
C. They improve the presentation of the drawing
D. They explain the drawing

6. Which drawing would **best** show how a product is assembled?

A. Exploded isometric
B. Orthographic
C. Freehand
D. Perspective

Notes / Activities

7. Which drawing technique demonstrates foreshortening?

A. Freehand
B. Isometric
C. Perspective
D. Orthographic

8.(a) State **one** advantage of developing a freehand perspective drawing for use with consumers.**(1)**

8. (b) Explain why a designer would produce both an orthographic drawing and an isometric drawing of a product. **(3)**

9 (a) State **one** advantage of an isometric drawing.**(1)**

Notes / Activities

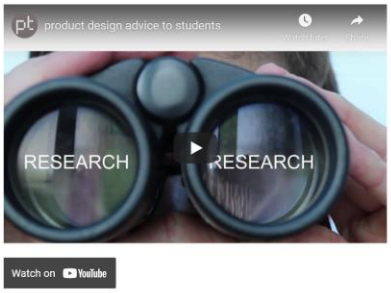
Topic 3.3: Physical Modelling

3.3 PHYSICAL MODELLING

Essential Idea:
A physical model is a three-dimensional, tangible representation of a design or system.

Essential Understanding
Designers use physical models to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. The primary goal of physical modelling is to test aspects of a product against user requirements. Thorough testing at the design development stage ensures that an appropriate product is developed.

Aim
Physical modelling not only allows designers to explore and test their ideas, but to also present them to others. Engaging clients, focus groups and experts to interact with physical models of products allows designers to gain valuable feedback that enable them to improve the design and product-user interface



3.3 PHYSICAL MODELLING

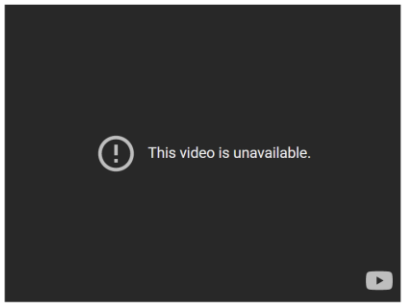
Concepts and principles:
- Scale models
- Aesthetic models
- Mock-ups
- Prototypes
- Instrumented models

Guidance:
- Applications of physical models
- Use of instrumented models to measure the level of a product's performance and facilitate ongoing formative evaluation and testing
- Advantages and disadvantages of using physical models

APPLICATIONS OF PHYSICAL MODELS

Physical modelling not only allows designers to explore and test their ideas, but to also present them to others. Engaging clients, focus groups and experts to interact with physical models of products allows designers to gain valuable feedback that enable them to improve the design and product-user interface.

A physical model can be used to obtain important data such as test and simulation measurements. Modelling, using physical models allows the user to better understand the problem and presents a means for manipulating the object in order to analysis the results of various tests or other changing situations.

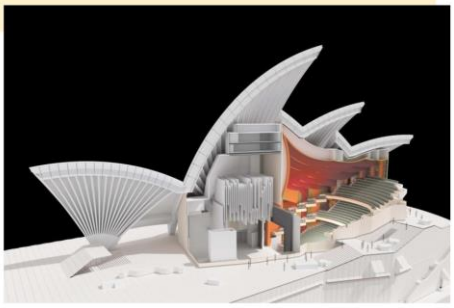


Notes / Activities

SCALE MODELS

A model that is either a smaller or larger physical copy of an object. A good example of scale models is seen in architecture, whereby a full-size building is modelled at a greatly reduced scale. This enables designers to visualize the structure of the building, but also the exterior and interior aesthetics and lines. The purpose of a smaller scale model may be to have a better overview, for testing purposes.

The purpose of a larger scale model may be to see the structure of things that are normally too small to see properly or to see at all, for example, a model of an insect or of a molecule.



Architectural Model scaled down

DNA Model scaled up

AESTHETICS MODELS

Aesthetic models are developed to look and feel like the final product.

The models are models look realistic to the product they are trying to represent. They are used for many purposes including ergonomic testing and evaluating visual appeal. Aesthetic models look like but do not work like the final product.

Aesthetic models can be relatively simple, consisting of solid chunks of foam finished and painted to look like the real thing, or they can be more sophisticated, simulating weight, balance and material properties. It is usually made from clay, foam, rubber, plastic or wood.

They can be used for ergonomic testing, evaluating visual appeal, allow the non-designer to see and feel how the real product will be, or production engineers collect data that will help them assess the feasibility for matching manufacturing systems.

BMW clay modelling

MOCK UPS

Mock-ups are used to test ideas and catch design flaws at an early stage. They are full-size or scale representations of a product used to gain feedback from users. A mock-up can be considered a prototype if it includes some functionality.

Mock-ups are commonly used by product designers, architects, and engineers. The intention is often to produce a product replica, using inexpensive materials in order to verify a design.

Mock-ups are often used to determine the proportions of the piece, relating to various dimensions of the object itself, or to fit the piece into a specific space or room. The ability to see how the design of the piece relates to the rest of the space is also an important factor in determining size and design.

Notes / Activities

PROTOTYPE

A prototype is a sample or model built to test a concept or process, or to act as an object to be replicated or learned from. A prototype is a model that includes functionality. Prototypes look and feel like the real production item but are produced as an one-off to provide a full evaluation before production.

At this point changes can still be made and more prototypes might be produced. They allow marketing departments starting advertising campaigns and show the product to distributors before the production starts.

PROTOTYPE - FIDELITY RANGE

In the fields of modelling and simulation, fidelity refers to the degree to which a model or simulation reproduces the state and behaviour of a real world object, feature or condition. Fidelity is a measure of the realism of a model or simulation. Simulation fidelity has also been described in the past as "degree of similarity".

Range of fidelity	*Low*	*Medium*	*High*
Type of Model	*conceptual representation (comparable in certain respects) to the idea*	*representation of aspects of the idea*	*as close as possible to the final product*

INSTRUMENTED MODELS

Instrumented Model – Prototypes that are equipped with the ability to take measurements to provide accurate quantitative feedback for analysis.
They can be used effectively to investigate many phenomena such as fluid flows in hydraulic systems or within wind tunnels, stress within structures and user interaction with a product.
For example, an instrumented model of a keyboard can record the actions of the user and provide data on how often keys are used and the number of errors a user makes (that is, the number of times the backspace or delete key is used).
These models can be scaled in terms of both geometry and important forces.

Mercedes-Benz SLS AMG Development and Testing Wind tunnel

PHYSICAL MODELLING

The main applications for physical modelling are

- *Product design*
- *Architecture and Engineering*
- *Medical research*
- *Automotive industry*

Make a list of the advantages and disadvantages of using physical models.

Notes / Activities

1. *How do physical models help the designer?*
2. *Is it only the designer who is helped by physical models?*
3. *What might be a limitation of an aesthetic model?*
4. *What are mock-ups used for?*
5. *When and why are scale models used?*
6. *What is the difference between a mock-up and a prototype?*
7. *What are the different ranges of fidelity?*
8. *List the different context ranges?*
9. *What is the purpose of instrumented physical models?*

Exam style questions

1. In the design development stage why is clay used to create a full-size model of a new car design?
A. It is cheap.
B. It is easy to manipulate.
C. It is readily available.
D. It makes the designer's role less complex.

2. What is not true of a clay model?
A. It can be used to test forces
B. It requires skill to develop
C. It looks like the intended outcome
D. It can be used to communicate design ideas to clients

2018
3. James Dyson reportedly made over 5000 prototypes before he was happy with the design of his vacuum cleaner, see Figure 5.
What could be a disadvantage of a detailed working prototype?
A. Looks different to the final product
B. Encourages inaccurate feedback
C. Does not give an accurate idea of the final product
D. Expensive to produce

Figure 5: A Dyson vacuum cleaner

2017
4.Figure 6 shows an Xbox 360 controller that has a curved shape case made of a thermoplastic material.
The Xbox 360 Controller has four action buttons, coloured and labelled as X, Y, A and B as well as two rubber thumb sticks that are buttons covered with a rubber-like material.
The design team would have used various types of models in the development of the Xbox 360 Controller.

Explain why the design team would have used physical modelling to test the ergonomic characteristics of the Xbox 360 controller. [3]

Figure 6: Xbox 360 controller

5. Outline one reason why appearance prototypes are expensive to produce. (2)

7. Define the purpose of a mock-up. (1 mark)

8. Explain 2 advantages of using a physical model. (2 marks)

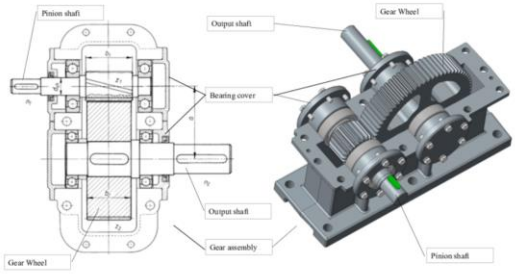
9. Explain and is an instrumented physical modelling and name an example you know. (3 marks)

Notes / Activities

Topic 3.4: Computer Aided Design (CAD)

Essential idea
A computer-aided design is the generation, creation, development and analysis of a design or system using computer software.

Essential understanding
As technologies improve and the software becomes more powerful, so do the opportunities for designers to create new and exciting products, services and systems. Greater freedom in customization and personalization of products has a significant impact on the end user. The ability to virtually prototype, visualize and share designs enhances the whole design cycle from data analysis through to final designs.



Aim
The use of CAD to simulate the conditions in which a product will be used allows the designer to gain valuable data at low cost. For example, simulating the flow of air across a car exterior negates the need for a car and wind tunnel.

Principles and concepts
- ➔ *Types of CAD software*
- ➔ *Surface and solid models*
- ➔ *Data modelling including statistical modelling*
- ➔ *Virtual prototyping*
- ➔ *Bottom-up and top-down modelling*
- ➔ *Digital humans: motion capture, haptic technology, virtual reality (VR), and animation*
- ➔ *Finite element analysis (FEA)*

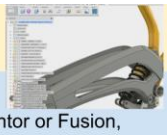
Guidance
- ➔ *Advantages and disadvantages of using computer-aided modelling*
- ➔ *How data models structure data through database models*
- ➔ *Design of information systems to enable the exchange data*
- ➔ *How haptic technology, motion capture, VR and animation can be used to simulate design scenarios and contexts*
- ➔ *Comparison of FEA with testing physical models*
- ➔ *Use of FEA systems when designing and developing products*

What is CAD?

Computer Aided Design (CAD) – *The use of computers to aid the design process.*

CAD is using computers to aid the design process, this could include creating and modifying designs (products), graphic design, data processing, analysis (FEA) or simulations.

Types of CAD Software



2D software
Examples :
2D Design
Adobe Illustrator
Corel Draw

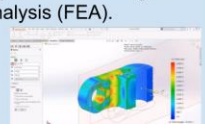
2D CAD software operates in the x and y axes.

Uses
- to create digital drawings that can communicate concepts and information to a client;
- Serve as a foundation for refining a design;
- Some 2D drawing file formats (DFX, for example) can be used to by CAD equipment such as laser cutters and routers;
- Presentation of schematic drawings such as circuits, floor plans, etc.

3D software
Examples: Autodesk Inventor or Fusion, SketchUp or Solidworks

Software that creates a 3D model in the 3 axis x, y and z, that contains information about about the dimensions, materials, etc. of the design. This information can be used to produce the design using CAM.

Uses
- Creation of parametric models that can be used by CAM equipment to produce the final product;
- Present and explore concepts before going into production or prototyping;
- Calculate material properties of a design using Finite Element Analysis (FEA).



Rendering
Examples: 3D Studio Max
Blender
Maya
Fusion, Inventor & Solidworks

Software that creates a realistic, but virtual representation of a design. This is used to present the design concept to clients and for advertising.

Uses
- presentation of design to clients
- preparation of advertising and promotion materials

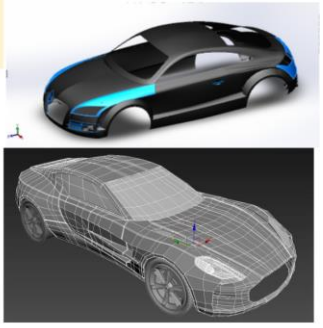
Notes / Activities

Advantages and Disadvantages of Using Computer-Aided modelling

Advantages	*Disadvantages*
• *Changes to ideas can be made quickly and easily.* • *Communicate with client, manufacture more easily.* • *Electronically transferred.* • *Avoid costly mistakes.* • *Reduce costs as extra prototypes are not needed.* • *Saves time through efficient work practises.* • *High accuracy/fidelity.*	• *Software/Hardware costs.* • *Special training needed.* • *Steep learning curve.*

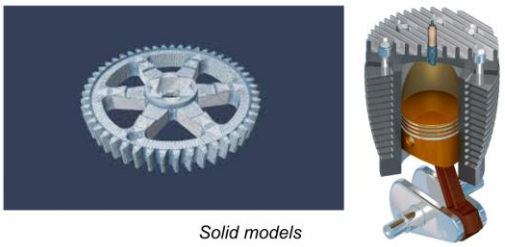
Surface and Solid Models

Surface Modelling *sometimes called rendering, only communicates information about the surface of the design. Rendering software uses data about the surface qualities, material, lighting, etc., to create a virtual representation of the product. There is* ***no information about the interior of the product, the parts, or components****. These types of models are usually presented as 2D graphics files (JPEG, PNG, TIFF, etc.) or animated videos. Blender, Maya, and 3D Studio Max are examples of surface modeling programs.*



Surface models

Solid models *on the other hand, are* ***accurate digital models of the whole part or object****. They contain information that can be used by CAM hardware to produce the part or object. Solid model file formats include STL, commonly used for 3D printing.*



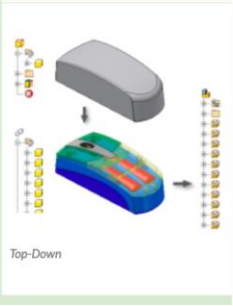
Solid models

Bottom-Up and Top-Down Modelling

"Top down" *design is a product development process obtained through 3D, parametric and associative CAD systems. The main feature of this method is that the design* ***originates as a concept which gradually evolves into a complete product*** *consisting of* ***components*** *and* ***sub-assemblies.***

- Related parts are connected, if one dimension is changed, associated dimensions on other parts will also be adjusted.

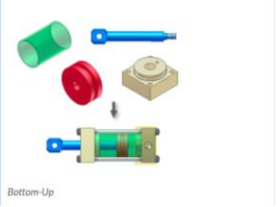
- The final design is a collection of interrelated parts that are uniquely design.



Top-Down

"Bottom Up"
A designer creates part geometry independent of the assembly or any modelling other component. Although there are often some design criteria established before modelling the part, this information is not shared between models. Once all parts are completed, they are brought together for the first time in the assembly.
This allows for a database of parts that could be used elsewhere.

-There is no relationship between parts - if a dimension is changed, associated dimensions must be changed individually



Bottom-Up

Notes / Activities

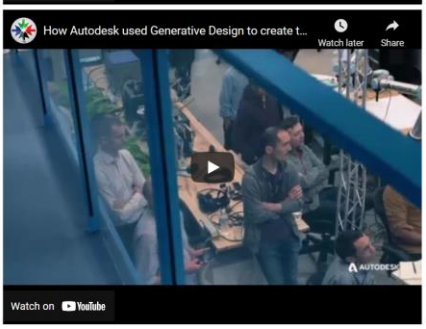
Data Models

Logo Pro Analysis Video

These types of models typically consist of a database or data set that is used to present and or understand the performance for a design. Data modeling is based on the requirements for for the use context or application.

Data models can be structured either as a flat, hierarchical or relational databases.

Using motion capture technology, accurate data can be gathered to understand the performance and design context.



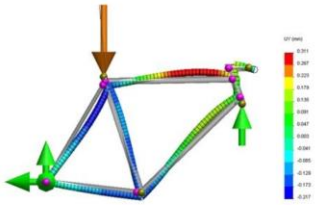
David Benjamin on how his team used Generative Design technology to create the new office space in Toronto by using the data gathered from employee preferences.

Finite element analysis (FEA)

Finite Element Analysis (FEA) is the calculation of loads and stresses on a product using CAD software. FEA uses a computer model of an object that is then analyzed to how it reacts when certain stresses such as heat, force, or load are applied.

FEA is a powerful tool that allows a designer to virtually evaluate the suitability, durability, and strength of design before producing a costly physical prototype. It substantially decreases the time from design concept to product reality.
Two common forms of FEA that a product designer might perform are:

- *Fatigue: to analyze the durability of a product. To determine where cracks might propagate in the design*
- *Heat: to analyze how heat is transferred through the product. To determine where hot spots might be in a design and if these may degrade the design*

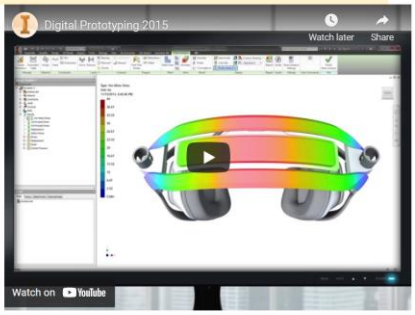


FEA analysis of the bicycle frame above shows areas of great stress (Red), and low stress (Blue)

Virtual Prototyping

Virtual prototyping is a software-driven modelling process that simulates products and environments by mimicking real world behaviours. It is finding increasing application in the development and testing and assessment of products.
Virtual prototyping finds application across a wide range of industries such as carmaking, white goods, yellow goods (construction), aerospace and consumer products.

- *Designers can simulate a design visually and/or mathematically*
- *Reduce lead times and development costs - the cost-effectiveness offered by animation and virtual reality. This helps to reduce full-scale prototyping, which leads to a reduction in tooling costs, labour costs, energy and materials*
- *Reduce or eliminate errors (as humans are not involved)*
- *Easily scalable – such as in nanotechnology or aeroplanes.*



Autodesk video showing the design process, from sketch to virtual prototype.

Notes / Activities

Digital humans

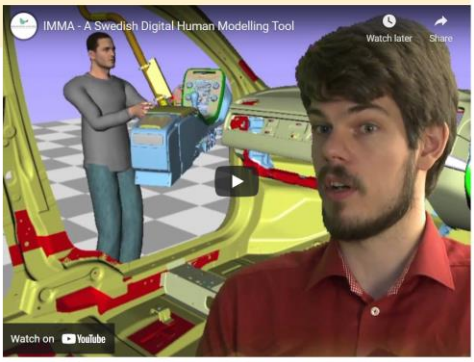
Digital simulations of the biomechanics of the human body. These kinds of models are used to predict how humans will move and interact with a virtual prototype. It allows for the gathering of information relative to the range of human motion, forces, fatigue, potential injury, etc. Using digital models of humans designers can analyze and confirm:

Safety and Comfort

- *ensure there is enough space to perform a maintenance task*
- *ensure that controls are accessible and adjustable (Can the dashboard controls of the car be reached by a seated and belted passenger?)*
- *ensure that tasks do not require excessive force to perform by hand (Can a handle be turned comfortably?)*

Efficiency

- *ensure equipment, controls, and machines are positioned to save time and avoid hazards*



The video above shows how digital humans are used to design the cockpit (interior) of cars, as well as the manufacturing assembly line

Siemens has a great article on using digital humans in product design, manufacturing - see link
https://www.plm.automation.siemens.com/global/en/products/tecnomatix/

Motion capture

Motion capture has been employed to assist with the understanding of human factors, physical limitations of the user and product evaluation.
Motion capture technology is used to record, track and analyse movement. The process records movement through a series of snapshots generated many times per second. The captured movements are mapped to a 3D human virtual model created by a computer artist. This process allows the computer model to replicate the movements and actions of the original human model. Once recorded, motion animation such as filmmaking may be generated. The information may also be used directly for the purposes of motion study, or the interaction of human motion with the natural or built environments.
Motion capture saves times and creates more natural movements than the alternative - manual animation.

Haptic technology (also known as force feedback technology)

*Haptic technologies use the **sense of touch** to provide **feedback to the user**. When interact with haptic technologies when our mobile phone vibrates when you press a button. More recently, some touch pads on notebook computers provide haptic feedback to the user as the move the mouse around the screen. It is also used in many gaming consoles*

Remote surgery systems rely on haptic feedback to communicate to the surgeon the nuance of the operation.

This haptic glove, the AxonVR, uses micro-pockets of air in the touch surfaces to communicate touch to the user.

Can the sense of touch be harnessed with technology? The field of haptics explores the revolutionary: interactive touch technology. At TEDYouth 2012, Katherine Kuchenbecker discusses how haptics has the potential to change fields as disparate as museums, dentistry, and stroke rehabilitation.

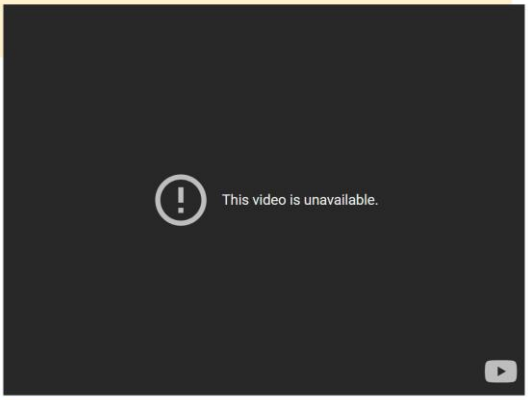
Notes / Activities

Virtual reality

*Virtual reality technologies create a **virtual environment** where the **user can interact with it in a realistic way**. VR technologies rely on **wearable technologies** such as a helmet and goggles as well as haptic technologies to provide feedback to the user.*

As seen in the video of Ford's Immersive Vehicle Environment Lab, VR technologies can provide valuable feedback about the design, ergonomics, use, and safety of a design. Because of its virtual nature, changes can be easily and quickly tested, saving time and development costs.

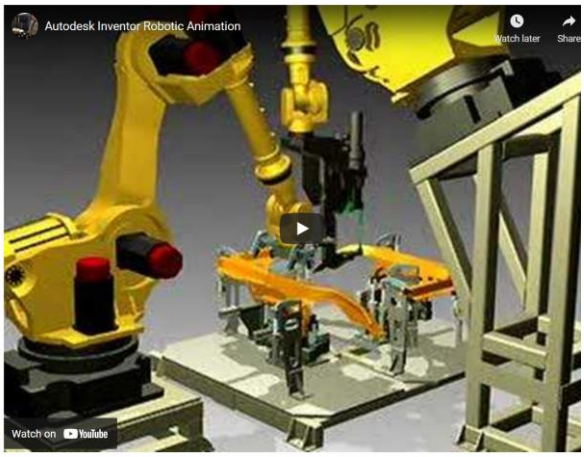
In addition, valuable data can be gathered about how users interact and use a product.



Ford motor company uses VR to test and analyse cabins of their vehicles. The VR units use haptic devices to provide a real sense of space.
VR provides a valuable feedback with regard to layout and mapping of controls. It provides also feedback on the interior in terms of ergonomics and what can be seen outside the car cabin

Animation

***Animation** …The ability to link graphic screens together in such a way as to simulate motion or a process.*
Animation can be used to simulate various designs contexts using digital humans to allow different scenarios to be tested.
Manufacturing companies can see how safe production will be when their products are being made through computer animations, without having to risk worker safety at any point.



Guiding questions

1. **Compare** surface and solid modelling
2. **State** the stage of the design cycle that virtual prototypes used
3. **Identify** the difference between bottom up modelling and top down modelling?
4. **Explain** how digital humans can improve design development.
5. **List** the benefits of using digital humans
6. **List** the different ways of capturing motion in motion capture
7. **State** what motion capture does not record
8. **Outline** some uses of haptic technology
9. How is motion capture, digital humans and animation connected?
10. **Outline** how animations are used in an industrial context
11. **Define** FEA
12. **Compare** FEA with testing physical models
13. **Explain** how FEA can be used to allow the redesign areas of weakness discovered through FEA
14. **Compare** animation and virtual reality – Refer to different design contexts. Consider costs, client needs and development time.

Notes / Activities

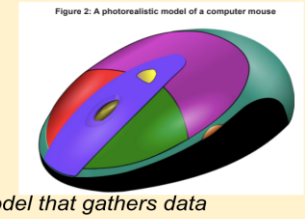
2019
1. Which type of analysis would you use to simulate unknown factors, such as stresses within a joint, in products?
A. Market analysis
B. Finite element analysis (FEA)
C. Life cycle analysis (LCA)
D. Work flow analysis

Nov 2019
2. Figure 3 shows people in a museum. By interacting with the exhibit they are able to understand how the image displayed on the screen feels.
Which technology enables the people to understand what the image feels like through their sense of touch?
A. Animation
B. Haptic
C. Motion capture
D. Virtual prototyping

Figure 3: People interacting with an exhibit in a museum

Nov 2018
3. Figure 2 shows a photorealistic model of a computer mouse. The model gives no internal data for manufacture using computer-aided manufacturing (CAM).
What type of model is shown in Figure 2?
A. Solid model
B. Graphic model
C. Surface model
D. Physical model

Figure 2: A photorealistic model of a computer mouse



2017
4. During the development of an electronic product, a designer builds a model that gathers data relating to button presses.
What type of model has been created?
A. An aesthetic model
B. A mock-up
C. An instrumented model
D. A conceptual model

Nov 2016
5. Which type of CAD has the ability to link graphic screens together in such a way as to simulate motion or a process?
A. Haptic technology
B. Animation
C. Motion capture
D. Virtual reality (VR)

2019
6.The design of a car is a process that has many stages. As a result, there can be a large number of prototypes and drawings used.
Some car designers are still using clay to make their first prototype of a new model of car, see Figure 3.

(dii) Describe the difference between surface and solid modelling. [2]

(eii) Explain why digital humans are used in car interior design. [3]

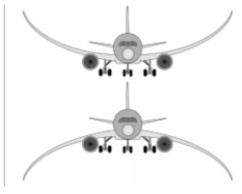
Figure 3: The use of a full-sized clay model

Nov 2018
7. The Boeing 787 aircraft was designed to be 20% more fuel efficient than its predecessors and is based on light-weight construction. The Boeing 787 is the first major commercial aircraft to have a composite fuselage, composite wings, and to use composites in most other components, see Figure 1.
The Boeing 787's cabin windows are larger than any other civil aircraft and are composed of photochromatic smart glass.
Figure 2 shows the use of an instrumented model during the development of the aircraft's wings.

(c) (i) List two advantages of using finite element analysis (FEA) for the design of the Boeing 787 wings. [2]
(
c) (ii) Explain how instrumented models have been used in the development of Boeing 787 wings. [3]

Material	Percentage of the total weight
Composites	50%
Aluminium	20%
Aluminium alloy/titanium alloy	15%
Steel	10%
Other	5%

Figure 2: Boeing 787 passing a wing stress test

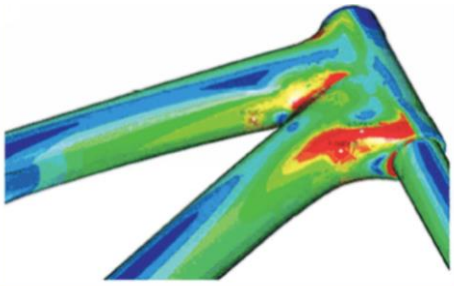


Notes / Activities

8. The figure below shows finite element analysis (FEA) data for part of a bicycle frame.

(a) Describe what the colours on the figure above mean. (2)

(b) Outline how the FEA image data shown in the figure above would be used by a designer. (2)



Exam style questions

Figure D3 shows a gymnast wearing a haptic textile suit. This technology provides feedback to the gymnast in order to perfect her routine.

Figure D3: Gymnast wearing a haptic technology suit

[Source: Picture courtesy of Birmingham City University © Centre for Excellence in Posture, Movement & Handling]

(a) Describe how haptic output device technology helps the gymnast to perfect her routines. [2]

10a) Explain how motion capture is used to digitally represent motion. (3)

b) Explain one limitation of a designer relying exclusively on human factors from digital humans. (3)

11. Car designers need to run tests to gather data relating to the protection of occupants in a collision.

a) Outline one way in which the use of digital humans can contribute to the tests. (2)

b) Outline one limitation of using digital humans for the tests (2).

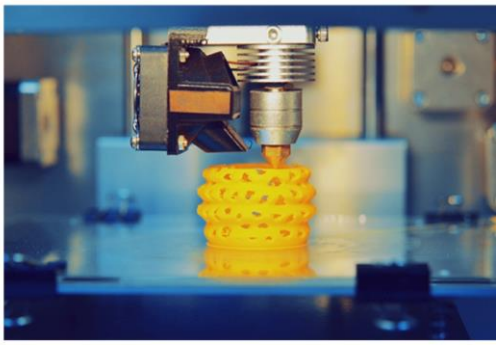
c) Outline one way in which digital humans can increase the speed of the product cycle. (2)

12. Discuss 3 reasons why car manufacturer often use animation to promote new vehicles on their websites. (9)

Notes / Activities

Topic 3.5: Rapid Prototyping

The growth in computing power has had a major impact on modelling with computer-aided manufacture. Rapid software and hardware developments allow new opportunities and exciting new technologies to create dynamic modelling of ever-greater complexity. Models can be simulated by designers using software, tested and trialled virtually before sending to a variety of peripheral machines for prototype manufacture in an ever-increasing range of materials. The ease of sending this digital data across continents for manufacture of prototypes has major implications for data and design protection.



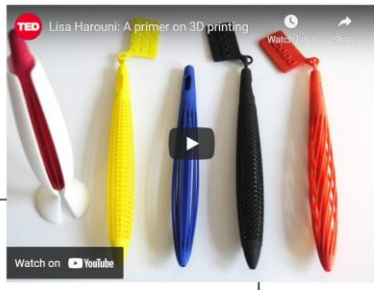
The increasing effectiveness of rapid prototyping techniques in terms of both cost and speed enables designers to create complex physical models for testing.

Concepts and principles:

- Stereolithography
- Laminated object manufacturing (LOM)
- Fused deposition modelling (FDM)
- Selective laser sintering (SLS)

Rapid Prototyping (RP) and RP Machines

- entails a machine that produces a complete product including internal details, at a fairly quick rate.
- reduce product development time as prototypes are quickly made and can be tested
- one-off products are made for different or specialised situations
- is an additive manufacturing technique as opossum to subtractive manufacturing (mills, lathes, etc).
    - less waste (good for environment and save money)



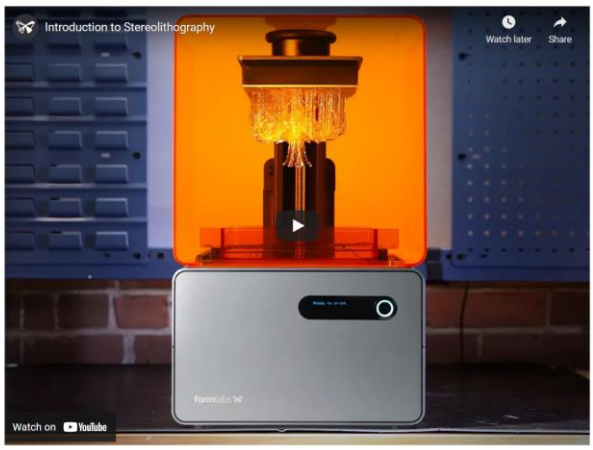
RP Process

- Using CAD software produce a full scale model
- Export or convert model in STL (Standard Triangle Language and Standard Tessellation Language).
- send to RP machine
- manufacture the item
- clean up the item

Stereolithography

Stereolithography (SLA) is a 3D printing process.

- that uses a vat of photosensitive resin and a vertically moving platform.
- It uses a laser beam, directed onto the surface of the photosensitive resin, to print the pattern of the current model layer by hardening the photosensitive resin.
- The platform then moves down by a layer thickness so the next layer can be printed.
- Also known as optical fabrication, photo-solidification, solid free-form fabrication and solid imaging.
- Used for producing models & prototypes, casting patterns, production parts and products.



Notes / Activities

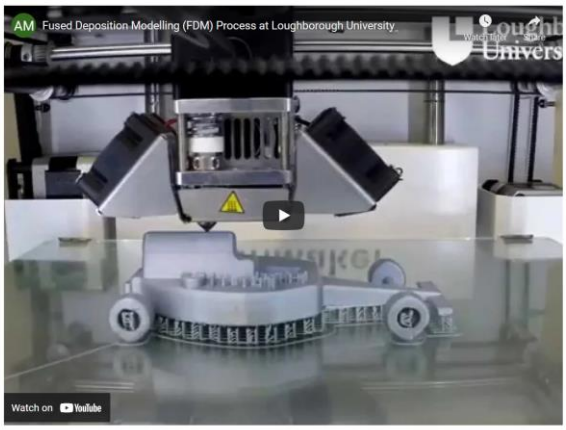
Laminated object manufacturing (LOM)

- LOM machines take the sliced CAD data from the 3D model and cut out each layer from a roll of material, using a laser or plotter cutter. These sliced layers are glued together to form the model, which is either built on a movable platform below the machine or on pins when using card. *(IB TSM 2015)*
- A rapid prototyping systems that creates a 3D product by manufacture (LOM) converting it into slices, cutting the slices out and joining the slices together

Fused deposition modelling (FDM)

A FDM machine is

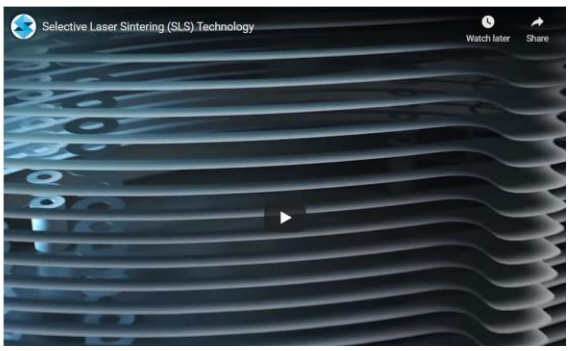
- A heated extrusion nozzle (extruder) that moves through the x & y axis
- A plastic (such as ABS, PLA), metal or composite (such as30% metal, bamboo, etc fill PLA) filament is fed through he extruder
- basically a CNC robot that holds a small extrusion head. The extrusion head moves back and forth along a platform, building up a 3D model by feeding heated plastic wire through the extrusion head.
- Either the platform or extruder move through the Z axis place a layer if build material
- Controlled by CAM software.



Selective laser sintering (SLS)

SLS is a 3D printing process based on sintering.

- A high powered CO2 laser is used to sinter a thin layer of heat-fusible powder that gradually builds up the 3D model.
- Powders include, plastic, metal, ceramics and glass



Notes / Activities

Advantages and disadvantages of rapid prototyping techniques

Advantages:	Disadvantages:
• Decrease development time • Decrease costly mistake • Increase number of variants of product • Increase product complexity • Increase effective communication • Rapid Prototyping can provide with concept proof that would be required for attracting funds.	• Some people are of the opinion that rapid prototyping is not effective because, in actual, it fails in replication of the real product or system. • It could so happen that some important developmental steps could be omitted to get a quick and cheap working model. This can be one of the greatest disadvantages of rapid prototyping. • Another disadvantage of rapid prototyping is one in which many problems are overlooked resulting in endless rectifications and revisions. • One more disadvantage of rapid prototyping is that it may not be suitable for large sized applications. • The user may have very high expectations about the prototype's performance and the designer is unable to deliver these.

Summary Notes
Q&A

Topic 3
Modelling

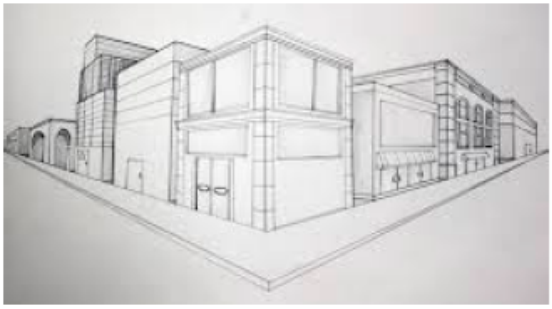
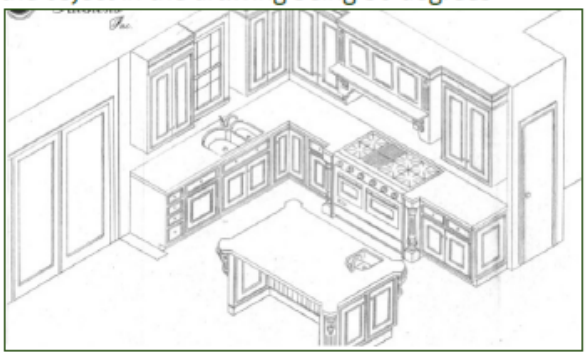
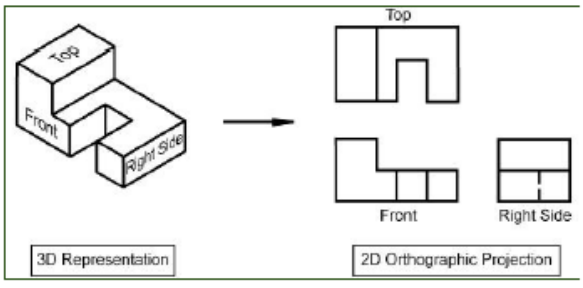
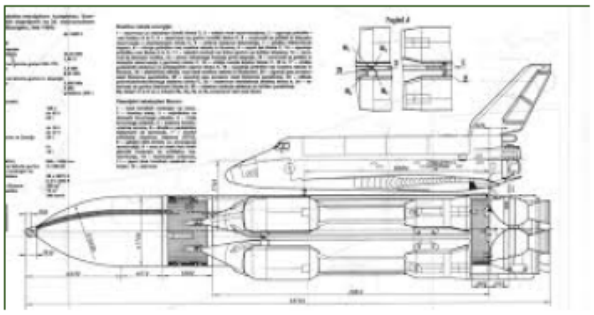
3.1 Conceptual modelling

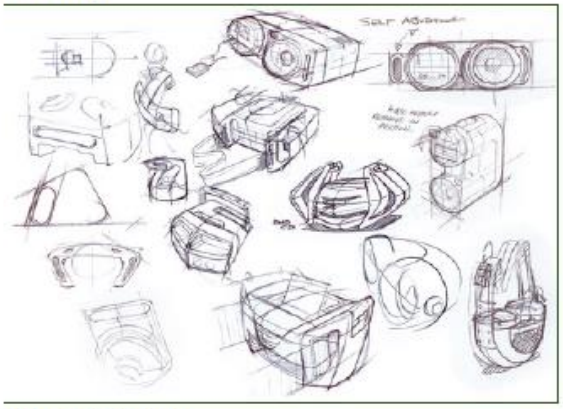
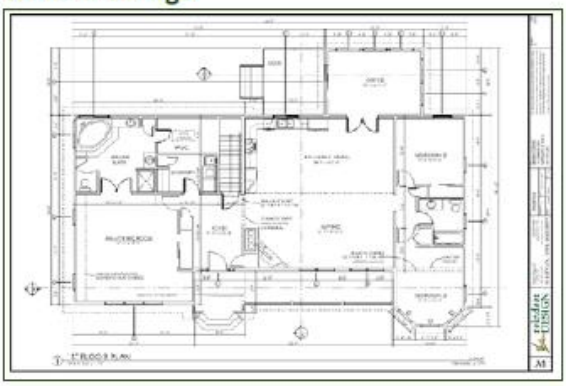
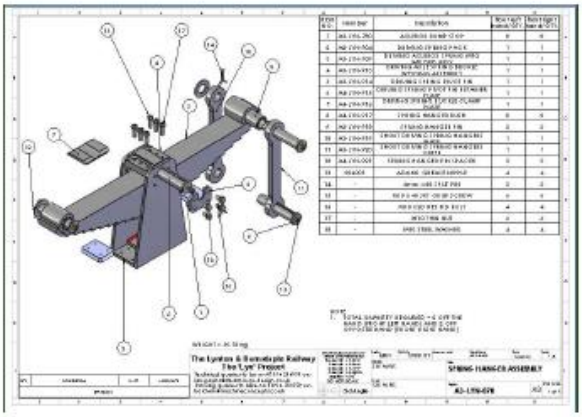
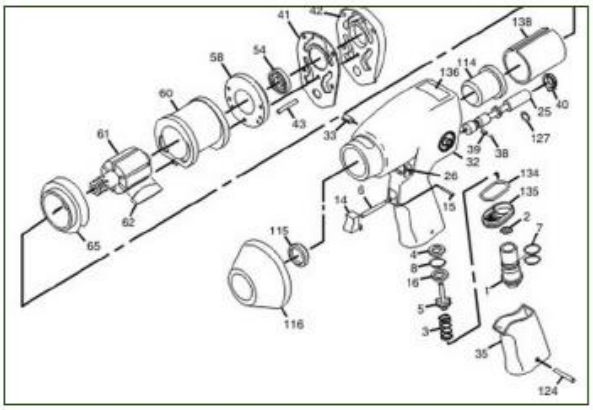
A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system. Designers use conceptual modelling to assist their understanding by simulating the subject matter they represent. Designers should consider systems, services and products in relation to what they should do, how they should behave, what they look like and whether they will be understood by the users in the manner intended.

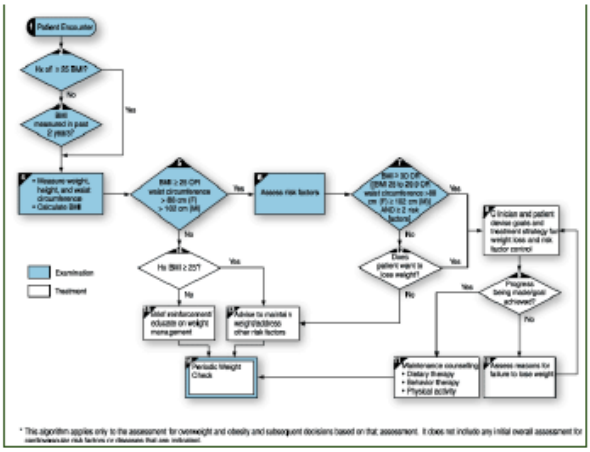
<table>
<tr><td>What is the role of conceptual modelling in design?</td><td>A conceptual model originates in the mind and its primary purpose is to outline the principles, processes and basic functions of a design or system. Conceptual models are used to help us know and understand ideas. Concept models are useful for communicating new ideas that are unfamiliar to people.</td></tr>
<tr><td>How do conceptual models vary in relation to the context?
What are some of the conceptual modelling tools and skills needed?</td><td>Conceptual models may vary in range from the more concrete , such as mental image that appears in mind, to the abstract mathematical models that do not appear directly in mind as an image. Conceptual models also range from scope of the subject they are representing. For example, they can represent either a single model (Statue of Liberty), whole classes of things (f.e. electron) or even a vast domains of subject matter , such as physical universe. Conceptual models are used to help us know and understand, design thinking, ideas, casual relationships, principles, data, systems, algorithms or processes.
Graphical Modelling
Sketches
Drawings
Flow charts
Physical Modelling
Card
Clay
Rapid prototype (3D printing)
Balsa wood
Blue styrofoam
Virtual Modelling:
Computer-Aided Design (CAD) Surface or Solid modelling, FEA, Data modeling</td></tr>
<tr><td>What is service design?</td><td>Service design is the activity of planning and organizing people, infrastructure, communication and material components of a service in order to improve its quality and the interaction between service provider and customers. The purpose to design according to the needs of the customers → so the product is user-friendly, competitive and relevant.</td></tr>
<tr><td>How are conceptual models used to communicate with oneself and others?</td><td>Concept models are used to communicate ideas that might be difficult to imagine otherwise. Designers use conceptual modelling to visualise and communicate ideas by simulating what they want to design.</td></tr>
<tr><td>What are the advantages and disadvantages of using conceptual modelling?</td><td><table><tr><th>Advantage</th><th>Disadvantage</th></tr><tr><td>-Shares ‘Big Picture’
-Makes it easy for non-designers and non-technical people to understand a complex idea
-Communication with clients and users
-Gauge people's reaction to concept or idea</td><td>-Lacks detail
-Can be misinterpreted
-Scale models can be misleading when the product is smaller or larger
-Materials may not reflect the final choice of materials- difficult to emulate</td></tr></table></td></tr>
</table>

3.2 Graphical modelling

Graphical models are used to communicate design ideas. Graphical models can take many forms, but their prime function is always the same—to simplify the data and present it in such a way that understanding of what is being presented aids further development or discussion. Designers utilize graphical modelling as a tool to explore creative solutions and refine ideas from the technically impossible to the technically possible, widening the constraints of what is feasible.

What	What they are used for	What they look like
What is a graphical model?	A graphical model is a 2D and 3D graphical models/visualization of an idea, often created on paper or through software.	They are drawings that convey the designers idea.
Perspective drawings	To show what a product will look like when finished in a more lifelike way.	Informal drawing technique on the 3D view of the design. The lines of a perspective drawing head towards a vanishing point. 
Isometric drawings	Used to accurately show what a product will look like when it is finished	You can recognise these drawings by an angle of the object in the drawing being 30 degrees 
Orthographic Projection	A way of drawing an 3D object from different directions. Usually a front, side and plan view are drawn so that a person looking at the drawing can see all the important sides. Orthographic drawings are useful especially when a design has been developed to a stage whereby it is almost ready to manufacture. Final , can be put to manufacture. Must always have at least 3 views.	
Scale drawings	All drawing techniques that show an object in proportion to its actual size. It is used when something needs to be presented accurately or either for planning or manufacturing.	

Sketching versus formal drawing techniques	**Sketching:** Spontaneous and free hand representation used very early in the design process. Usually free hand **Adv**: Communicate the ideas very quickly among the colleagues. **Dis**: can't take the idea to manufacture. **Formal drawings:** Ruled out and accurate drawings. The techniques tend to be used in the development phase of a design process. Formal drawings are used to represent a more resolved idea, something that the designer has settled on or wishes to investigate the idea in more detail. **Adv**: Shows in detail sizes of concept, Can be used to construct, Accurate, Different views of object shown that couldn't see from a 3D drawing **Dis**: Time consuming, Requires high level of skill, Specialist drawing equipment needed	**Sketching:**  **Formal drawings:** 
Part drawings	A **part drawing** provides the information to assembly a product in a similar way that an assembly drawing does with additional benefit of having a list of parts [LOP] or Bill of Materials [BOM]. A drawing of individual parts to help know which part is broken and how to repair it.	
Assembly drawings **(Exploded isometric)**	An **assembly drawing** shows how parts of a product fit together. They are often used to show how to assemble parts of model kits and flat-pack furniture. There are two types of assembly drawings. A **fitted assembly drawing** shows the parts put together, and can be drawn in 2D or 3D. An **exploded assembly drawing** that shows the parts separated, but in the correct relationship for fitting together. Exploded views are usually drawn in 3D.	

Algorithm	In mathematics and computer science, an algorithm is a self-contained step-by-step set of operations to be performed. Seen here with a flow chart.	

3.3 Physical modelling

A physical model is a three-dimensional, tangible representation of a design or system. Designers use physical models to visualize information about the context that the model represents. It is very common for physical models of large objects to be scaled down and smaller objects scaled up for ease of visualization. The primary goal of physical modelling is to test aspects of a product against user requirements. Thorough testing at the design development stage ensures that an appropriate product is developed.

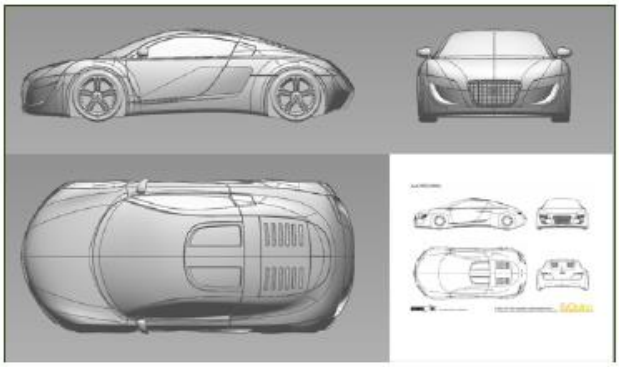
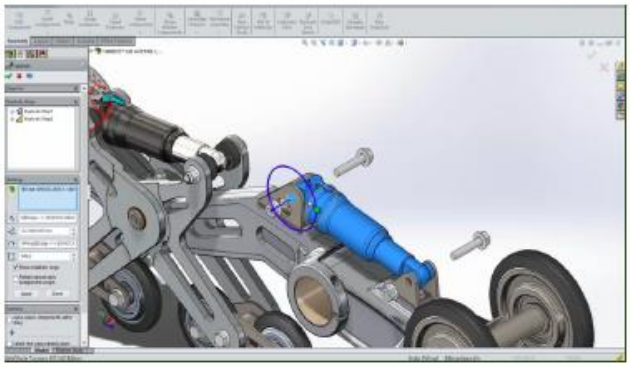
Term	Definition	Example/advantages & disadvantages
What is **Physical modelling?**	A physical model is a three-dimensional, tangible representation of a design or a system. 'Appearance Model'	 **Advantages:** -They allow the user to visualize the product and identifying any problems with the product easily. -The user can understand how the product would look in a real environment. **Disadvantages**: -It can be a time consuming process to create the physical model. -It can't be manipulated the same way a digital model can be.
Scale models	A **scale model** is a smaller or larger physical copy of an object. Scale models allow visualization, from examining the model, of information about what the model represents. A scale is usually represented e.g. 1:100 A good example of scale models is seen in architecture, whereby a full-size building is modelled at a greatly reduced scale. This enables designers to visualize the structure of the building, but also the exterior and interior aesthetics and lines.	 **Advantages:** -The model can be overviewed easily, especially if the original design is exceptionally large. -As it is scaled, it gives an idea of how large the model will be when it is actually produced/built. **Disadvantages:** -Can be time consuming to create a perfectly scale model. -Apart from providing the user with visual information about the product, it is hard to manipulate it to show how it works.

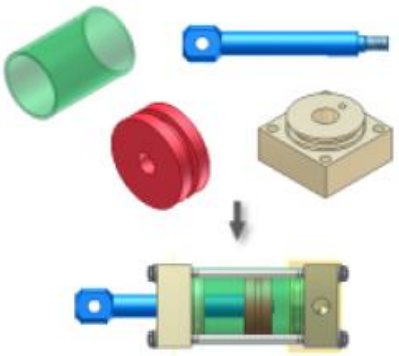
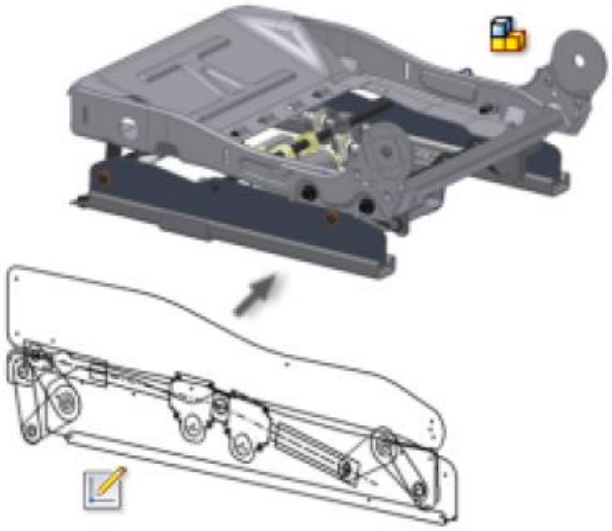
Aesthetic models	**Aesthetic models** are developed to look and feel like the final product. They are used for many purposes including ergonomic testing and evaluating visual appeal. Aesthetic models look like but do not work like the final product. Aesthetic models can be relatively simple, consisting of solid chunks of foam finished and painted to look like the real thing, or they can be more sophisticated, simulating weight, balance and material properties. Usually, aesthetic models are "for show" and are not designed to be handled excessively. They give non-designers a good representation of the feel and look of an object. For example, production engineers can take data to assess feasibility for matching manufacturing systems.	 **Advantages:** -They can be used instead of digital models to give the user an idea of how the product would look like in a real environment. -They can be used to give production engineers data to assess the feasibility of producing the product. **Disadvantages:** -They are non-working models and they only provide a visual model of the product. -They are fairly expensive to produce as the surface finish can be difficult to recreate.
Mock-ups	**Mock-ups** are used to test ideas. They are scale or full-size representation of a product used to gain feedback from users. A mock-up can be considered a prototype if it includes some functionality. Can have 'work-like' mock up and 'look-like' mock up.	 **Advantages**: -Can be used to get feedback from the user. -They are models made to a 1:1 scale and offer a full size representation of the product. **Disadvantages**: -Does not offer as much functionality as a prototype. -Can be difficult and time consuming to create.
Functional Prototypes	A **functional prototype** is a sample or model built to test a concept or process or to act as an object to be replicated or learned from. A prototype is used to test and validate ideas and can be used throughout design development. Prototyping can be used to provide specifications for a real, working product rather than a theoretical one. Prototypes are developed to work from two perspectives: the point of view of the development team, which can learn by creating the product, and the point of view of the user, from whom the development team can learn through user interaction and feedback. A prototype can be developed at different fidelities within a range of user and environment contexts.	 **Advantages:** -Is a semi to fully functioning model of a product and thus it can be used to test the functions of the final product out. -It can provide specifications for the parts involved in a real product and how they would function together. **Disadvantages:** -Can be slightly expensive to make as the prototype needs to be able to function. -Does not take aesthetics into account as it primarily tests the function of the product.

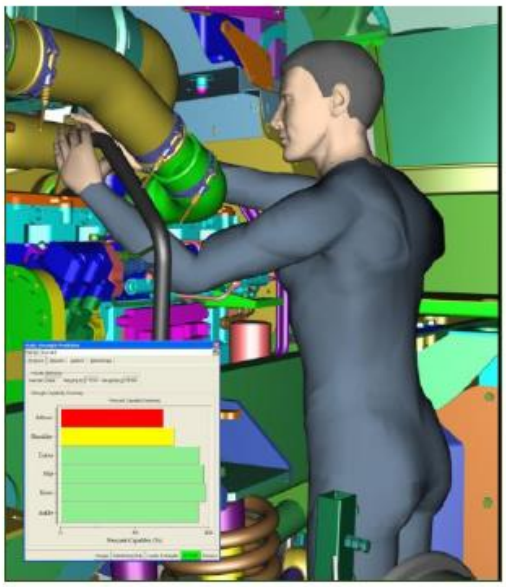
What is the **range of Fidelity**	Fidelity is a measure of the realism of a model or simulation. The range of fidelity is: ▪ **low** fidelity—conceptual representation analogous to the idea ▪ **medium** fidelity—representation of aspects of the idea ▪ **high** fidelity—mock-up of the idea, as close as possible to the final product	The range of contexts is: ▪ restricted—in a controlled environment ▪ general—any user, any environment ▪ partial—final user **or** environment ▪ total—final user **and** environment A combination of fidelity and context provides validation of an idea and/or further insight for development.
Instrumented models	**Instrumented physical models** are equipped with the ability to take measurements to provide accurate quantitative feedback for analysis. They can be used effectively to investigate many phenomena such as fluid flows in hydraulic systems or within wind tunnels, stress within structures and user interaction with a product. For example, an instrumented model of a keyboard can record the actions of the user and provide data on how often keys are used and the number of errors a user makes (that is, the number of times the backspace or delete key is used). These models can be scaled in terms of both geometry and important forces.	 **Advantages:** -Can be used to take accurate measurements related to the performance of the product, and can be used to improve the product further. -Can be used to record the dynamic behaviour of an object, in other words, data can be taken on how the product functions in a controlled environment. **Disadvantages:** -Can take time and be very expensive to set up.

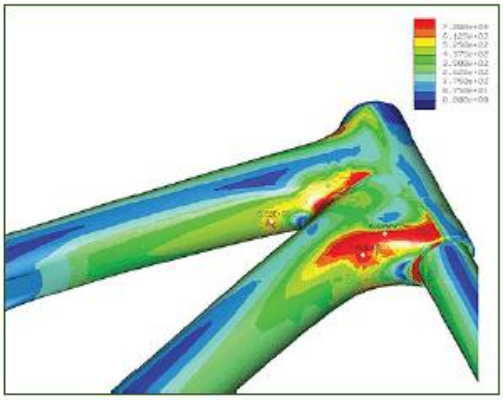
3.4 Computer-aided design (CAD)

A computer-aided design is the generation, creation, development and analysis of a design or system using computer software. As technologies improve and the software becomes more powerful, so do the opportunities for designers to create new and exciting products, services and systems. Greater freedom in customization and personalization of products has a significant impact on the end user. The ability to virtually prototype, visualize and share designs enhances the whole design cycle from data analysis through to final designs.

Term	Definition	Example/advantages & disadvantages
What is **CAD** and what is it used for	Computer-aided design. CAD is used for conceptual design and layout of product and can ultimately eliminate the high costs of testing and manufacturing. CAD is used in fashion, construction, automative, architecture and for planning electrical or mechanical layout.	-A computer-aided design is the generation, creation, development and analysis of a design or system using computer software. The use of CAD to simulate the conditions in which a product will be used allows the designer to gain valuable data at low cost.
Surface modelling	Surface models are photo-realistic images of a product, offering some machining data but no data about the interior of the product.	 -photo-realistic images of a product, offering some machining data -No data about the interior of the product.
Solid modelling	Solid models are clear representations of the final product. They provide a complete set of data for the product to be realized including internal dimensions and volume.	 Solid models are clear representations of the final product. They provide a complete set of data for the product to be realized including internal dimensions and volume.
Data modelling also known as Mathematical modelling/ Statistical modelling	A **data model** explicitly determines the structure of data or structured data including statistical modelling. Typical data models include databases and information systems	

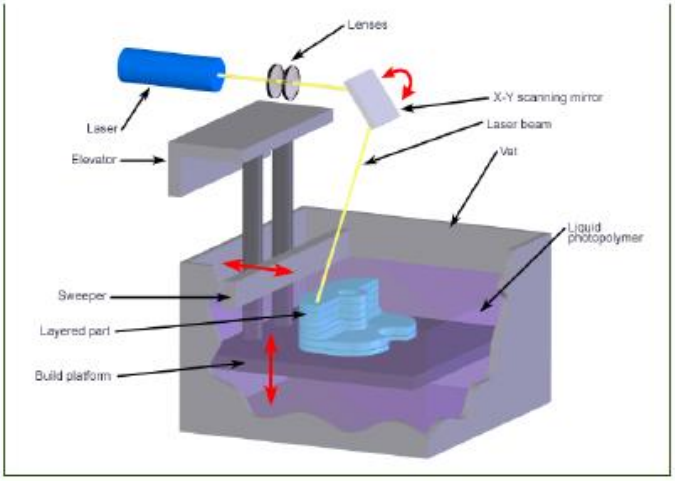
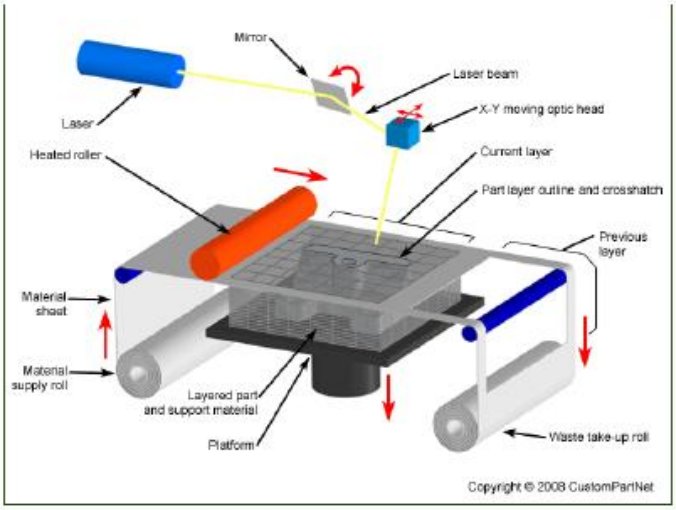
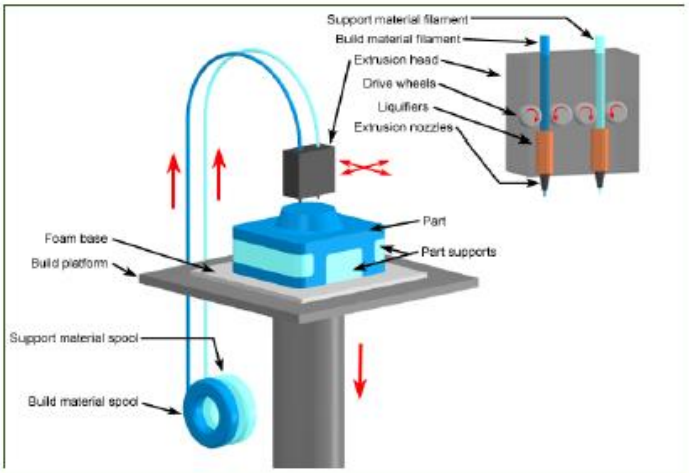
Virtual prototyping	Virtual prototyping involves the use of surface and solid modelling to develop photo-realistic interactive models. These can be considered digital mock-ups.	 Jaguar and Land Rover moving to virtual 3D vehicle prototyping
Bottom-up modelling	When designing using a "bottom-up" strategy, the designer creates part geometry independent of the assembly or any other component. Although some design criteria are often established before modelling the part, this information is not shared between models. Once all part models are completed, they are brought together for the first time in the assembly. For example, the process by which the Mars rover Curiosity was created followed a "bottom-up" strategy. Place existing parts and subassemblies into an assembly file, positioning components by applying assembly constraints, such as mate and flush. If possible, place the components in the order in which they would be assembled in manufacturing.	 Advantage: we know what the parts are. 
Top-down modelling	"Top-down" design is a product-development process obtained through 3D, parametric and associated CAD systems. The main feature of this method is that the design originates as a concept and gradually evolves into a complete product consisting of components and sub-assemblies. "Top-down" begins with the design criteria and create components that meet those criteria. Designers list known parameters and create an engineering layout. The layout can be a 2D design that evolves throughout the design process as shown in the following image.	

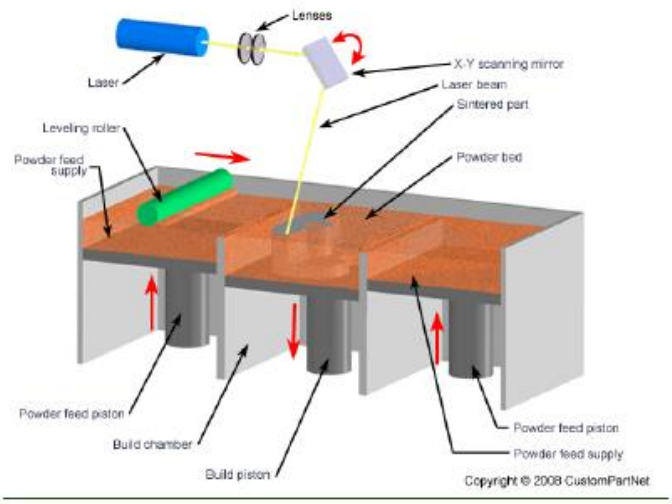
Digital humans	Digital humans are computer simulations of a variety of mechanical and biological aspects of the human body. They can be used to interact with a virtual prototype. Human simulation in product design enables a product to be developed more quickly, as there can be more design iterations in less time. This results in higher product quality that meets human requirements more accurately. Digital prototypes are cheaper to produce than physical prototypes. Products are safer as a result of more thorough analysis of safety aspects. Improved productivity results from enhanced automation of the development process.	
Motion capture	Motion capture is the recording of human and animal movement by any means, for example, by video, magnetic or electro-mechanical devices. A person wears a set of acoustic, inertial, LED, magnetic or reflective markers at each joint. Sensors track the position of the markers as the person moves to develop a digital representation of the motion. Motion capture can reduce the cost of animation, which otherwise requires the animator to draw either each frame or key frames that are then interpolated. Motion capture saves time and creates more natural movements than manual animation, but is limited to motions that are anatomically possible.	"Gollum" from Hobbit is a character formed by using Motion Capture filming technique. This character got an award winning for motion capture model. Compared to Avatar, Gollum appearance reveals all the muscle movements and skin reflection to the light, showing the technology improvement over the years. 
Haptic technology	Haptic technology is a technology that interfaces the user via a sense of touch. Also known as force feedback technology, haptic technology works by using mechanical **actuators** (motor) to apply forces to the user. By simulating the physics of the user's virtual world, it is possible to compute these forces into real time. Haptic technology allows the user to become part of a computer simulation and to interact with it, enabling the designer to observe the user's performance and to design a better outcome. It can also be used in situations where it is difficult to train in the real environment. Haptic technology is also used in feedback devices used in home entertainment consoles.	

Virtual reality (VR)	Virtual reality is the ability to simulate a real situation on the screen and interact with it in a near-natural way.	
Animation	Animation is the ability to link graphic screens together in such a way as to simulate motion or a process.	
Finite element analysis (FEA)	Finite element analysis involves the calculation and simulation of unknown factors in products using CAD systems, for example, simulating stresses within a welded car part. (virtual model) Uses colour indication to show: -Structural load (stress and strain) -Aerodynamics -Thermodynamics	

3.5 Rapid prototyping

Rapid prototyping is the production of a physical model of a design using three-dimensional **CAD data**. The growth in computing power has had a major impact on modelling with computer-aided manufacture. Rapid software and hardware developments allow new opportunities and exciting new technologies to create dynamic modelling of ever-greater complexity. Models can be simulated by designers using software, tested and trialled virtually before sending to a variety of peripheral machines for prototype manufacture in an ever-increasing range of materials. The ease of sending this digital data across continents for manufacture of prototypes has major implications for data and design protection.

What	How it works	Image of process
Stereolithography (SLA) (uses laser or light to set plastic liquid)	It is a form of **3D printing** using a liquid bath of resin combined with an **ultraviolet** laser. The ultraviolet light hits the liquid **hardening** it to form the structure of the object being printed. The **base plate** of the bath then moves down allowing **more liquid** to flow over the previously hardened liquid so the same process can be repeated until the object being printed has been **completed**. The 'Sweeper' seen in the image to the right just helps **even out** the height of the bath every time the laser fires.	
Laminated object manufacturing (LOM)	It takes the sliced **CAD data** from a 3D model and **cuts out each layer** from a roll of material, using a **laser or plotter cutter**. These sliced layers are **glued** together to form the model, which is either built on a **movable platform** below the machine or on locating pins when using card.	
Fused deposition modelling (FDM) (Same as school makerbot and Flashforge)	Uses an "additive" principle by **laying down materials in layers**. **Plastic/metal** is unwound from a coil and sent to an extrusion **nozzle** that can **turn the flow on and off.** The **nozzle is heated** to **melt** the material, nozzle moves in **horizontal and vertical directions** by a numerically controlled mechanism **(CAM)**	

Selective laser sintering (SLS) (uses laser to set plastic powder)	is an **additive** manufacturing technique that uses a **high-power laser** (for example, a carbon dioxide laser) to **fuse small particles of materials** such as plastic, metal (direct metal laser sintering), ceramic or glass powders into a mass that has a desired 3D shape.	
Advantages and Disadvantages of Rapid Prototyping	**Advantages** -Decrease development time -Decrease costly mistake -Increase number of variants of product (since each printed model takes lesser time to produce, the time saved can be used to develop more ideas, thus increase productivity). -Increase product complexity (more complex and difficult shapes can be modelled, which would perhaps not be possible with hand. For eg. sculpting out an accurate sphere in a material). -Increase effective communication (since the model is tangible, various aspects of the design would be easier to explain to others, as compared to CAD. Models can also be tested, which probably would be only possible through artificial simulation for CAD designs, and thus unlike prototypes, this would only give an approximate idea). -Rapid Prototyping can provide with concept proof that would be required for attracting funds (easier to explain, aesthetics can be focused on)	**Disadvantages** -Some people are of the opinion that rapid prototyping is not effective because, in actual, it **fails in replication** of the real product or system. -It could so happen that some important developmental steps could be omitted to get a quick and cheap working model. This can be one of the greatest disadvantages of rapid prototyping. -Another disadvantage of rapid prototyping is one in which many problems are overlooked resulting in endless rectifications and revisions. -One more disadvantage of rapid prototyping is that it may not be suitable for large sized applications. -The user may have very high expectations about prototype's performance and the designer in unable to deliver these. .

Topic Questions & Exam Practice

End of Topic Questions

1 Describe the term 'Conceptual Modelling'

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2 What is the difference between 'Conceptual Modelling' and Graphical Modelling' ?

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3 List 4 Graphical modelling Techniques

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4 A scale model is an example of.....1

5 Why is a scale model used?

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6 What is significant about Aesthetic models?

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7 State the difference between a 'Mock up' and a 'prototype'

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8 Complete the sentences below:

.....fidelity - representation of aspects of the idea 1

High fidelity - 1

Low..... - .....representation,.....to the idea.....1

9 The paper bone chair by Joris Laarman for Droog is an early study of the internationally acclaimed aluminum bone chair. The paper bone chair was made using an early rapid prototyping technique from layers of paper, see Figure 3.

Figure 3: The paper bone chair

What is the rapid prototyping technique called?

A. Fused deposition modelling (FDM)

B. Laminated object manufacturing (LOM)

C. Stereo-lithography

D. Selective laser sintering (SLS)

10 Graphical models are useful for engineers, manufacturers, designers and clients, and vary depending on the context. Which of the following graphical models is most appropriate in the context of an architectural design to present to a client?

A. Assembly drawing

B. Perspective drawing

C. Isometric drawing

D. Orthographic projection

11 Selective laser sintering can use a range of powdered materials to create products. These materials include...

A. Plastic, metal and glass

B. Ceramics, textiles and wood

C. Plastic, wood and composites

D. Metal, textiles and ceramics

12 Robots can be used to replace humans in a number of production areas. Which of the following is a potential disadvantage of using robots in production?

A. Perform repetitive tasks

B. Work in confi ned spaces

C. Loss of jobs

D. Highly accurate

13 Natural textile fibres are animal and plant based. Which of the following are properties of natural fibres?

A. High absorbency: Burns with a flame, but does not melt

B. Low absorbency: Melts when heated

C. High absorbency: Melts when heated

D. Low absorbency: Burns with a flame, but does not melt

14 Which of the following scales of production would be most appropriate for the Alpha Dog headphones?

A. Craft production

B. Mass production

C. Mass customization

D. Batch production

15 Describe the difference between additive and subtractive manufacturing. [6]

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16 Explain two advantages of combining computer-aided design (CAD) modelling with physical modelling to get feedback during design development of products. [6]

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17 Explain the difference between Die casting and Injection Moulding [3]

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18 List 3 reasons why clay modelling is still used to prototype models in processes such as car design. [3]

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19 Explain why digital humans would be used in testing design environments. [3]

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20 Explain how Prototype modelling can help inform designers, manufacturers and Consumers and products and their development. [9]

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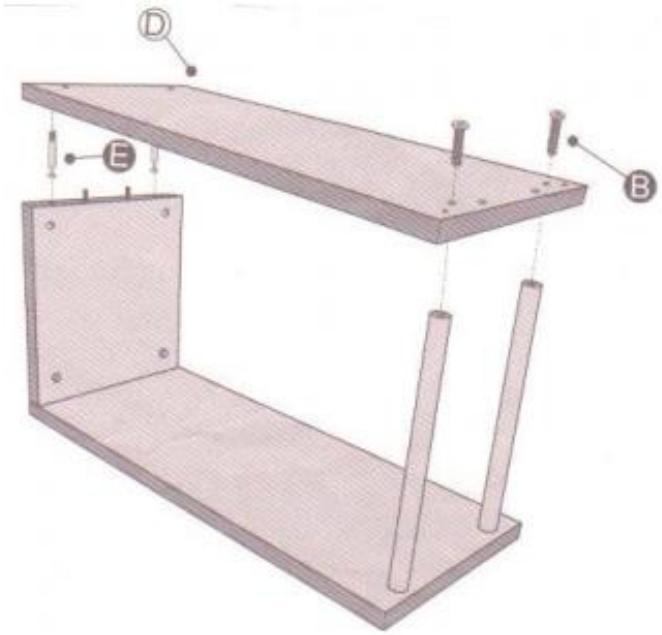
Exam Practice Questions

28. Outline **one** reason why appearance prototypes are expensive to produce. *[2]*

Figure 2: Flat-pack self-assembly wall unit



[Source: Geneva 6 Shelf Unit Assembly Instructions by Homebase LTD.]

(a) State the type of drawing shown in **Figure 2**. *[1]*

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(b) Discuss **one** advantage of this type of drawing for the consumer. *[3]*

(a) Explain **one** way in which digital humans can enhance human factors research in the development of ski clothing for competitive skiers. *[3]*

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(b) Explain how motion capture technology is used to create a digital human. *[3]*

Figure 8 shows the Water Craft life-saving aid designed by Ross Kemp as his final year project for his design degree. As a student, Ross undertook a lifeguard training course and realized that it was difficult to move a body through water single-handedly. Existing aids were either a paddle board or jet skis but these need two people to launch them. He based his new design on the jet ski but with a sloping back to make it easier to pull someone on it. After graduation, Ross decided to try and create a marketable version of his idea so he produced a number of prototypes to test. The initial testing with the Royal National Lifeboat Institution (UK) was not a great success so further prototypes were done to get to the pre-production stage. Funding for more testing at Bondi beach in Australia was gained after the Water Craft won first prize of £10 000 in the Lloyds TSB Enterprise competition and sponsorship was raised from the media attention. **Figure 9** shows a scale model of the Water Craft.

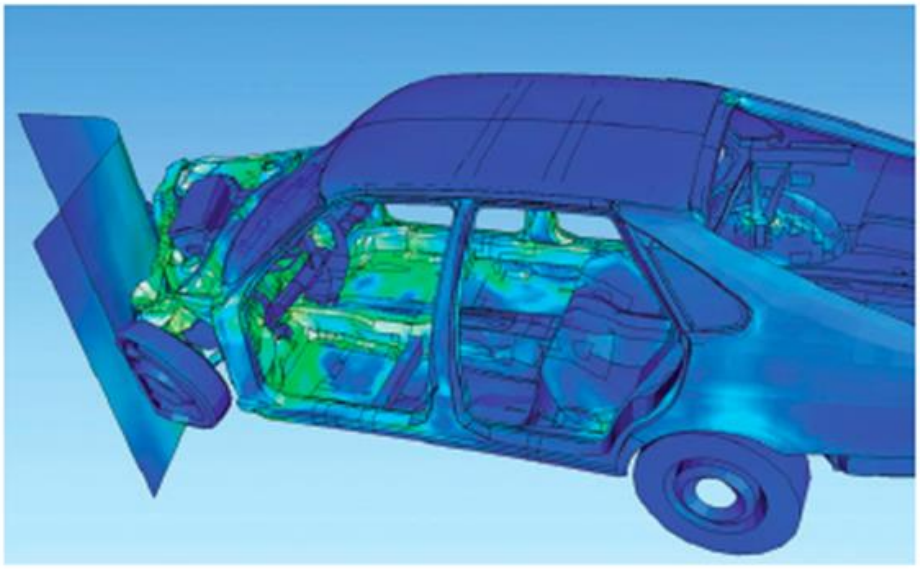
Figure 8: Water Craft prototype

Figure 9: Ross Kemp and scale model

(ii) Explain the reason for using scale models as part of the design development process for the Water Craft. [3]

Figure C2 shows a finite element analysis (FEA) CAD image of a crash (impact) test for a car.

Figure C2: FEA CAD image of a crash (impact) test for a car



ource: "FAE visualization". Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:FAE_visualization.jpg#/media/File:FAE_visualization.jpg]

(a) Describe the relationship of the dark and light colours in the FEA image shown in **Figure C2**. [2]

Outline **one** reason why the designer would carry out a series of tests to obtain reliable data from FEA CAD images similar to that in **Figure C2**. [2]

Explain **two** ways in which the use of rapid prototyping influences the design development cycle for a new product. [6]

Discuss **three** reasons why car manufacturers often use animation to promote new vehicles on their websites. [9]

Figure D3 shows a gymnast wearing a haptic textile suit. This technology provides feedback to the gymnast in order to perfect her routine.

Figure D3: Gymnast wearing a haptic technology suit

[Source: Picture courtesy of Birmingham City University © Centre for Excellence in Posture, Movement & Handling]

(a) Describe how haptic output device technology helps the gymnast to perfect her routines. [2]

(a) Explain how motion capture is used to digitally represent motion. [3]

(b) Explain **one** limitation of designers relying exclusively on human factors data from digital humans. [3]

E5. Car designers need to run tests to gather data relating to the protection of occupants in a collision.

(a) Outline **one** way in which the use of digital humans can contribute to the tests. *[2]*

(b) Outline **one** limitation of using digital humans for the tests. *[2]*

(c) Outline **one** way in which digital humans can increase the speed of the product cycle. *[2]*

Figure C2: Physical prototype made using stereo lithography

[Source: ProtoMED, Inc., www.protomed.net]

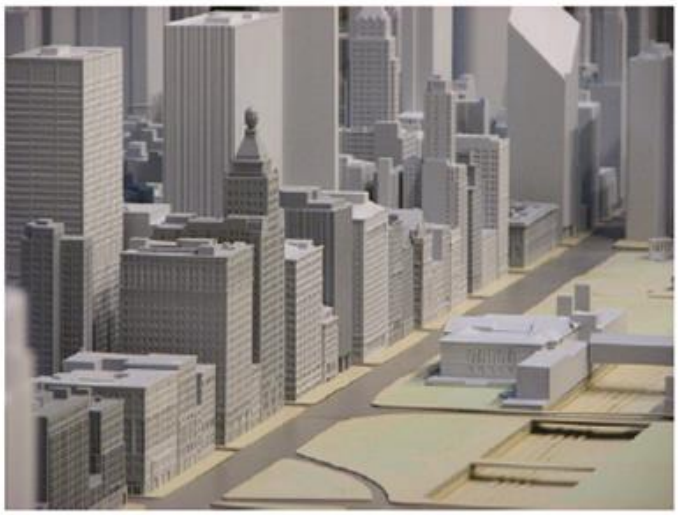
(a) Outline **one** advantage of stereo lithography for the production of a prototype for the designer. *[2]*

(b) Outline **one** advantage of stereo lithography for the production of a prototype for the manufacturer. *[2]*

C7. Discuss **three** advantages of using CAD when designing electronic product housing. *[9]*

The Chicago Architecture Foundation has built a model of the city (**Figure C1**). The 1000 buildings took 3000 hours to build using stereo lithography.

Figure C1: The Chicago Model City



[http://chicagomodelcity.org]

(a) State **one** reason why the production of the model city's buildings using stereo lithography resulted in very little waste. *[1]*

C3. (a) Outline **one** advantage of LOM as part of rapid prototyping. *[2]*

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(b) List **two** benefits of being able to rapid prototype a product. *[2]*

C7. Discuss how the use of Haptic Technology aids the design and use of virtual training in relation to user observation, training and feedback. *[9]*

CAD software can be used for "top down" or "bottom up" modelling of parts, components and complete products, such as the Moon exploration vehicle and its wheels (**Figure C2**).

Figure C2: Exploded solid CAD model of a Moon exploration vehicle

Outline **one** benefit of using "bottom up" modelling in the development of the solid CAD model of the Moon exploration vehicle. *[2]*

C4. The Haptic Workstation shown in **Figure C4** is a 3D haptics innovation from Virtual Realities. It is a fully integrated simulation system. **Figure C5** shows a virtual reality image.

Figure C4: Haptic workstation in use

[www.vrealities.com/hapticworkstation.html; Virtual Realities, Ltd.]

Figure C5: Virtual reality image

[Manager Mechanics virtual environment used with permission (www.ManagerMechanics.com).]

Explain **two** differences between haptic technology and virtual reality. *[6]*

Explain **two** advantages to the consumer of using virtual reality software in designing new buildings. *[6]*

(b) Explain **one** way in which digital human technology can be used with percentile data related to reach for wheelchair users in the design of a kitchen. *[3]*

Figure C3 shows a prototype design of a perfume bottle with its outer box.

Figure C3: Perfume bottle prototype and outer box

[Source: Designer: Erin Dameron, Brooklyn, New York]

Discuss **two** benefits of using rapid prototyping in the design development of the perfume prototype shown in **Figure C3**. *[6]*

Explain why producing a prototype is a form of modelling. *[3]*

Glossary of Terms

Glossary of Terms

Topic 3: Modelling

Term	Definition
Aesthetic models	A model developed to look and feel like the final product.
Animation	The ability to link graphic screens together in such a way as to simulate motion or a process.
Assembly drawings	A diagram that shows how components fit together to make a whole. Typically presented in an exploded view.
Bottom-up modelling	A designer creates part geometry independent of the assembly or any other component. Although there are often some design criteria established before modelling the part, this information is not shared between models. Once all parts are completed, they are brought together for the first time in the assembly.
Computer Aided Design (CAD)	The use of computers to aid the design process.
Conceptual modelling	A model that exists in the mind used to help us know and understand ideas.
Data Modelling	A model that determines the structure of data.
Digital human	Computer simulation of a variety of mechanical and biological aspects of the human body.
Fidelity	The degree to which a prototype is exactly like the final product.
Finite element analysis (FEA)	The calculation and simulation of unknown factors in products using CAD systems. For example, simulating the stresses within a welded car part.
Formal drawing techniques	A type of drawing technique that has fixed rules, the most widely used being isometric projection and perspective drawing.
Fused deposition modelling (FDM)	A 3D printing technique that places melted layers of material on a bed to build up a 3D model.
Graphical models	A visualization of an idea, often created on paper or through software, in two or three dimensions.
Haptic technology	Haptic technology is an emerging technology that interfaces the user via the sense of touch.
Instrumented models	Prototypes that are equipped with the ability to take measurements to provide accurate quantitative feedback for analysis.
Laminated object manufacturing (LOM)	A system that virtually slices a 3D CAD model into thin layers, then cuts out each layer from a roll of material using a laser or plotter cutter. The layers can then be glued in the correct order to create a 3D model.
Mock-ups	A scale or full-size representation of a product used to gain feedback from users.
Motion capture	The recording of human and animal movement by any means, for example, by video, magnetic or electro-mechanical devices.
Part drawings	Orthographic drawings of the components of an assembly containing details just about that component.
Perspective	A set of formal drawing techniques that depicts an object as getting smaller and closer together the further away they are. The techniques

drawings	are one-point perspective, two-point perspective, and three-point perspective.
Physical modelling	The creation of a smaller or larger tangible version of an object that can be physically interacted with.
Projection drawings	Systems of drawings that are accurately drawn, the two main types are isometric projection (formal drawing technique) and orthographic projection (working drawing technique).
Prototypes	A sample or model built to test a concept or process, or to act as an object to be replicated or learned from. Prototypes can be developed at a range of fidelity and for different contexts.
Scale drawings	Drawings that are bigger or smaller than the real product, but exactly in proportion with product.
Scale models	A model that is either a smaller or larger physical copy of an object.
Selective laser sintering (SLS)	An additive manufacturing technique that uses a laser to fuse small particles of material into a mass that has a desired 3D shape.
Sketches	Rough drawings of ideas used to convey or refine the idea.
Solid modelling	Solid models are clear representations of the final part. They provide a complete set of data for the product to be realized.
Stereo-lithography	A modelling technique that creates 3D models layer-by-layer by hardening molecules of a liquid polymer using a laser beam.
Surface modelling	A realistic picture of the final model, offering some machining data. Surface models contain no data about the interior of the part.
Top-down modelling	"Top down" design is a product development process obtained through 3D, parametric and associative CAD systems. The main feature of this new method is that the design originates as a concept and gradually evolves into a complete product consisting of components and sub-assemblies.
Virtual prototyping	Photorealistic CAD-based interactive models that use surface and solid modelling. They can be considered 'digital mock-ups'.
Virtual reality (VR)	The ability to simulate a real situation on the screen and interact with it in a near-natural way.
Working drawings	Drawings that are used to guide the production of a product, most commonly orthographical projection, section drawings, part drawings, assembly drawings and plan drawings.

DP DESIGN TECHNOLOGY

WITH

Mr Moneeb

TOPIC 3: Guidance and Notes Booklet
2020 - 2022