

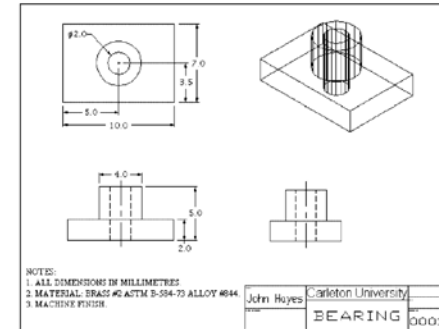
# ECOR 1010

## Lecture 7

Engineering Graphics - 3

# Engineering Graphics

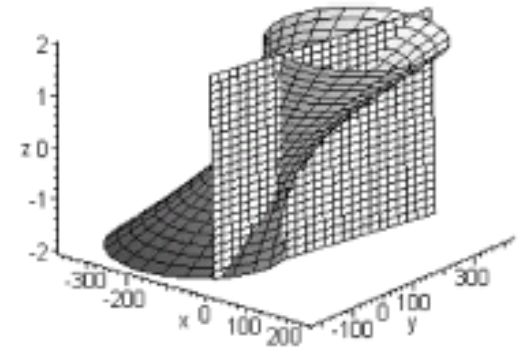
- Engineering graphics has evolved into six major areas, which overlap:
  - Descriptive Geometry (Engineering Drawing, as shown previously)
  - **Graphical Mathematics**
  - **Nomography**
  - **Empirical Equations**
  - Technical Illustration
    - in manuals, etc. used to communicate an idea, not necessarily technically exact.
  - **Engineering Computer Graphics: CAD**



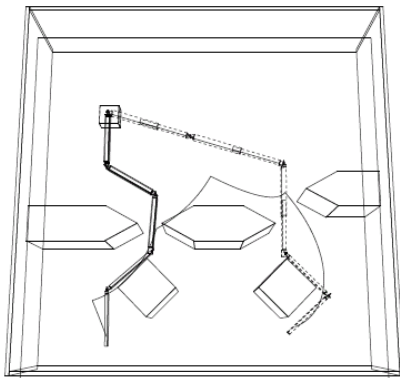
An important example of effective graphical communication.

# Graphical Mathematics

We may wish to find the intersection of all the possible positions a robot arm can have and a space in which it will operate.

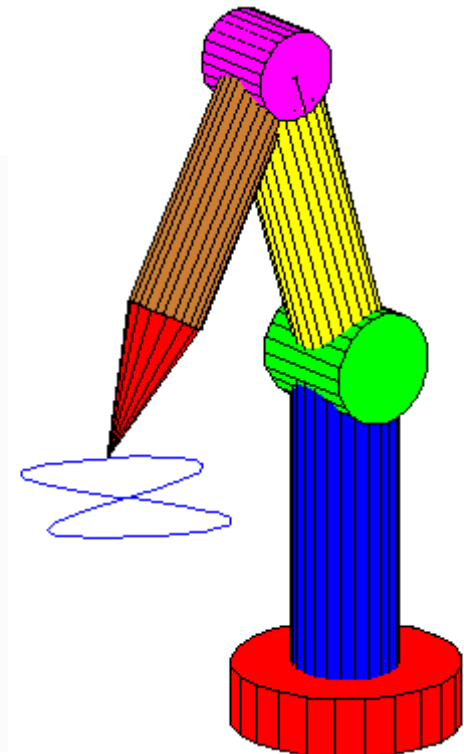
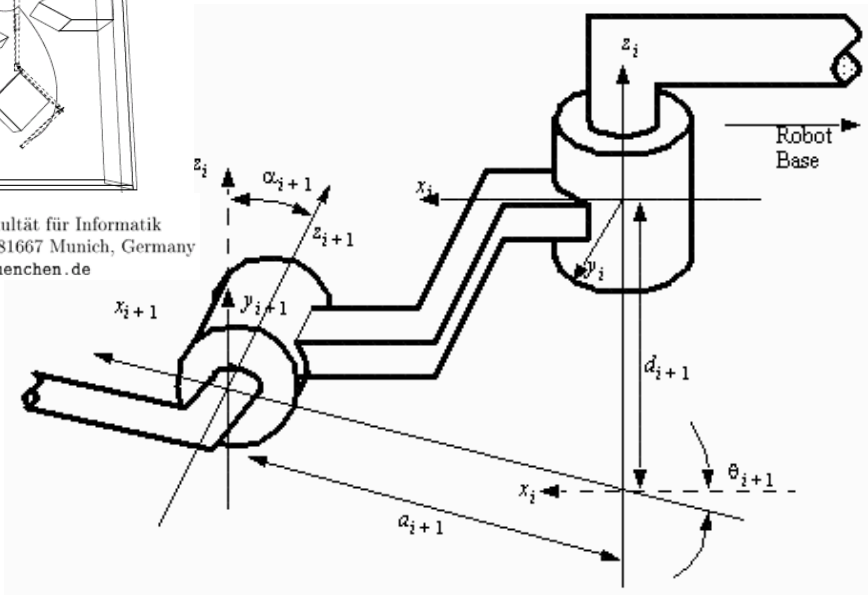


Intersection between a plane and an hyperboloid.



Boris Baginski

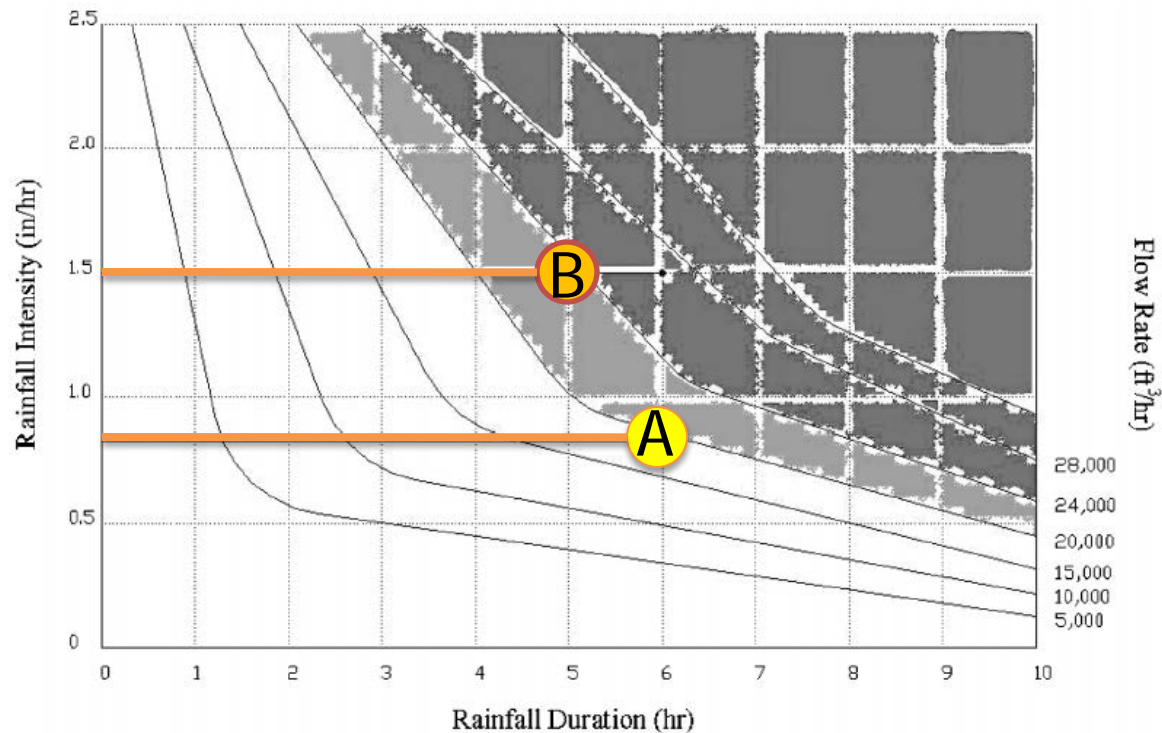
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# Nomographs

- A **nomograph**, also called an **alignment chart**, is a calculating chart with scales that contain values of three or more mathematical variables
- Widely used in engineering, industry, and the natural and physical sciences

# Nomograph example: Expected Flows in a river (Will it flood?):

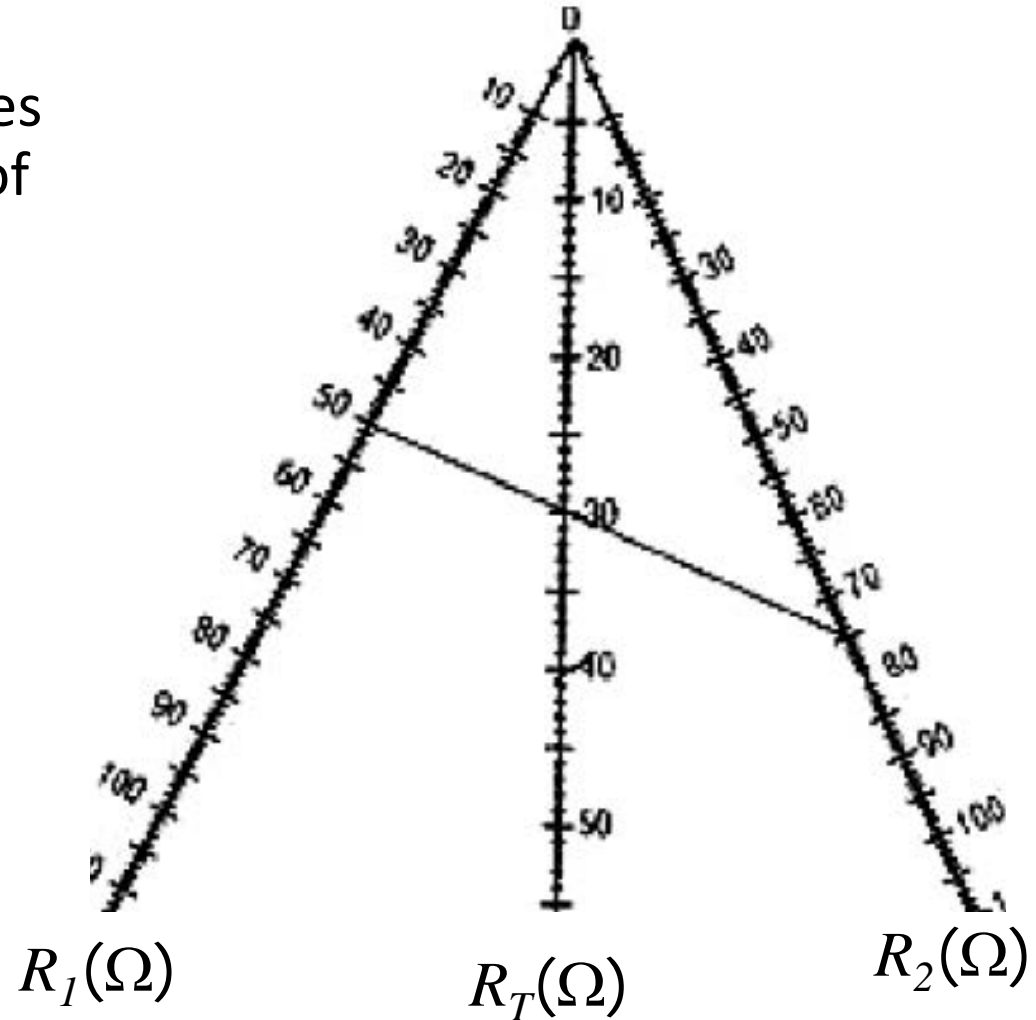


- A. It rains 5 inches in 6 hours, the average intensity is 0.83 in/h; the point on the chart falls closest to the curve for 22,000 cu ft/s: yellow "Flood Caution" zone
- B. It rains for 4 hours at an intensity of 1.5 in/h (for a total of 6.0 in). It is expected the rain will continue for another hour at the same rate, a flow level of ~23,500 ft<sup>3</sup>/s can be expected: flooding is highly likely!

# Parallel Resistor Nomograph

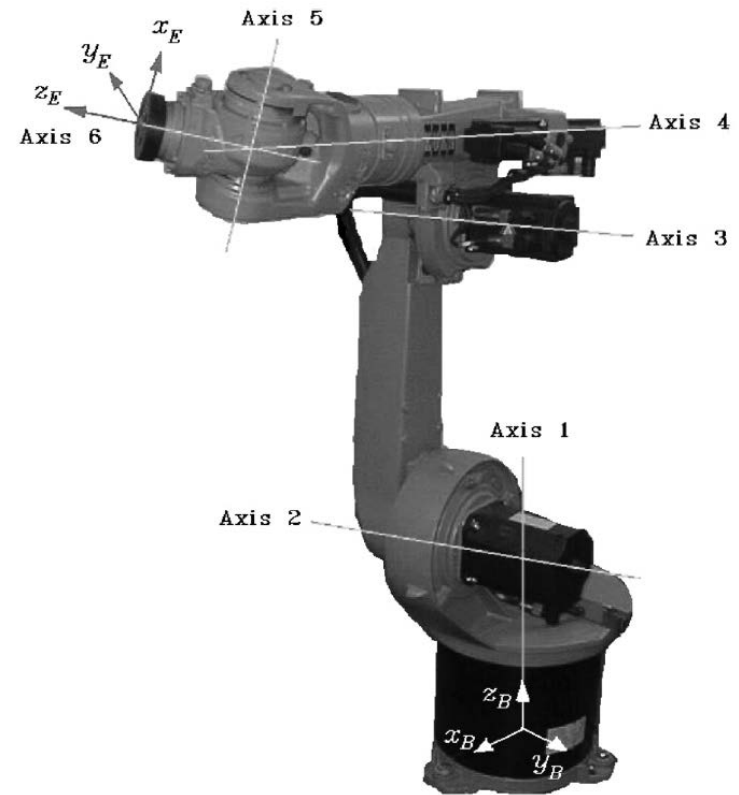
- This nomograph determines the equivalent resistance of two parallel resistors
- e.g., the equivalent resistance of a 50  $\Omega$  and a 75  $\Omega$  resistor in parallel is 30  $\Omega$

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$



# Empirical Equations

- Modeling relations between empirical data with mathematical equations
- Example: find an empirical equation to describe how different parts of a robot heat up from ambient conditions during the course of performing a continuous cyclic task



**Figure 12.33** A KUKA KR-15/2 industrial robot.

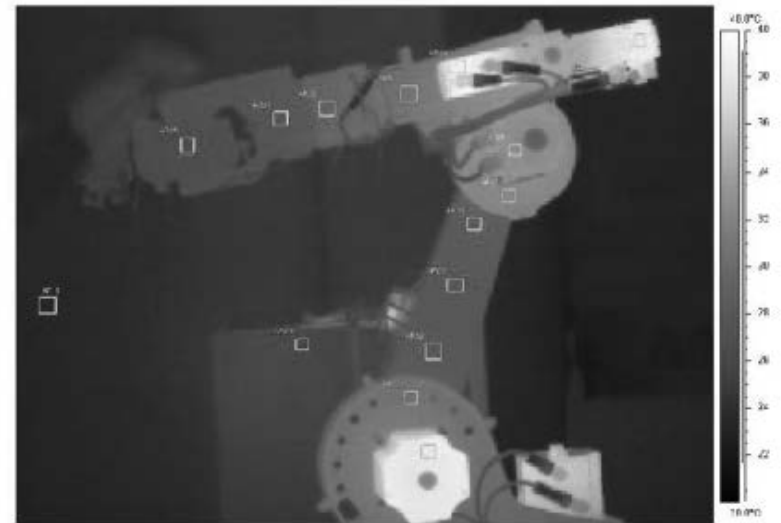
# Empirical Equations

- Infra-Red Thermogram (start)



(a)

- Infra-Red Thermogram (end)



(b)

**Figure 12.34** Infrared camera thermographs of robot: (a) cold start; (b) after 15 hours continuous operation.

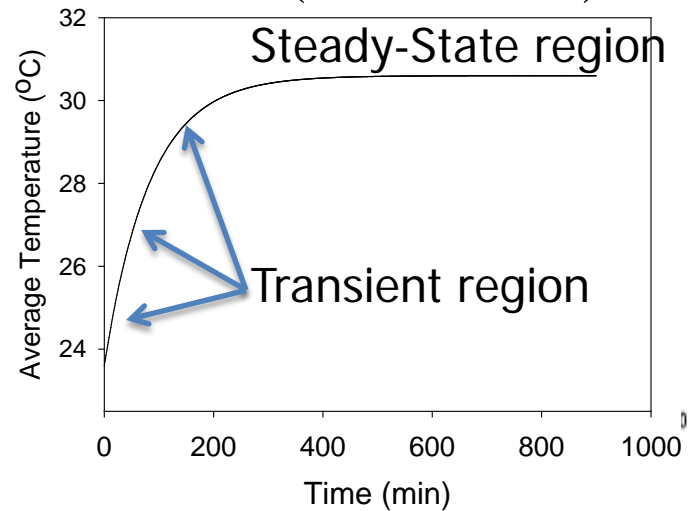
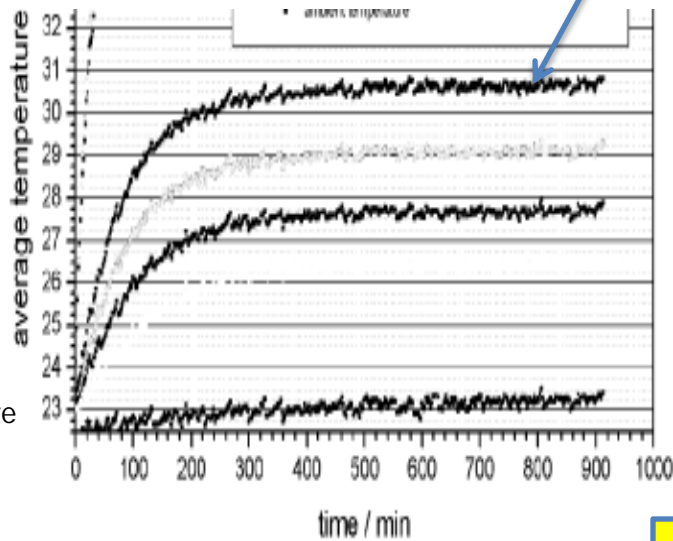
# Empirical Equations

Average temperature at measurement spots on lower arm

These data are modeled empirically with:

$$T = T_{ss} - (T_{ss} - T_o) e^{-(t/\tau)}$$

$$= 30.6 - (30.6 - 23.6) e^{-(t/83)}$$



This can be just an equation that fits the data, with no physics behind it, if the goal is an equation for interpolation ...

**Figure 12.35** Empirical data plots: (a) heat-up curves of areas on the end effector; (b) heat-up curve of a single area.

# Where do these equations come from?

- Three places:
  1. Any equation that reproduces the data in an ‘acceptable’ way can be used, IF the goal is to have an equation for interpolation.
    - This is called “curve fitting”.
  2. A theoretically-based equation that is derived from some physical insight.
    - this can be used for interpolation and extrapolation, within limits.
  3. Or, a combination of the above

# Where did we get:

$$\begin{aligned} T &= T_{ss} - (T_{ss} - T_o) e^{-(t/\tau)} \\ &= 30.6 - (30.6 - 23.6) e^{-(t/83)} \end{aligned}$$

Assume that the rate the temperature changes with time is proportional to how far the piece is from its final steady-state temperature:

$$\frac{dT}{dt} \propto T_{ss} - T$$

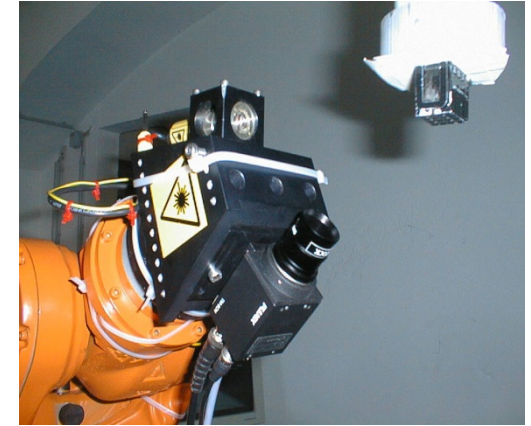
The proportionality constant we will call:  $1/\tau$ , where  $\tau$  is some 'time constant' that depends on the material properties. Hence,

$$\frac{dT}{dt} = \frac{1}{\tau} (T_{ss} - T)$$

We can now integrate this expression over the limits of the test, and determine the parameters for this model equation "empirically" by finding the values that make the equation 'fit' the data. We will learn how this is done when we study regression later.

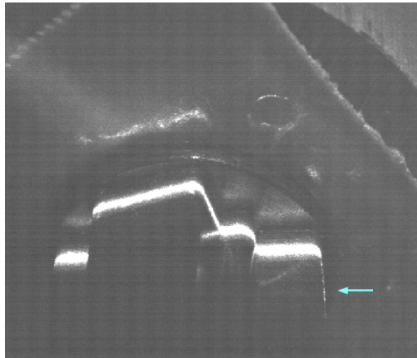
# Empirical Equations

- Integrated optical/robotic measurement system
- Application to rapid prototyping

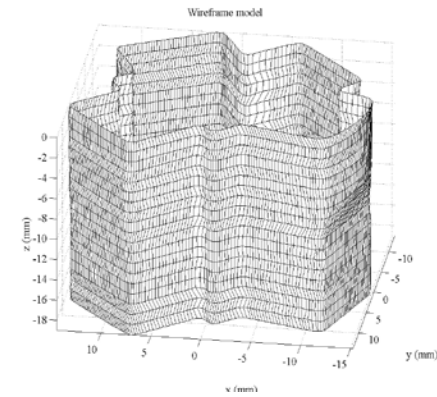


# Empirical Equations

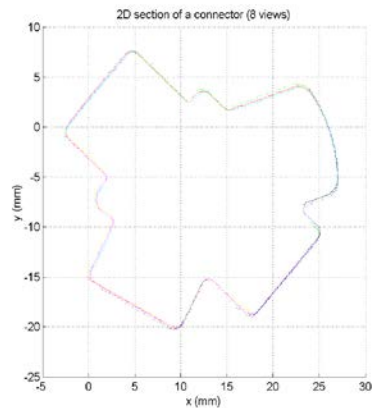
Raw image



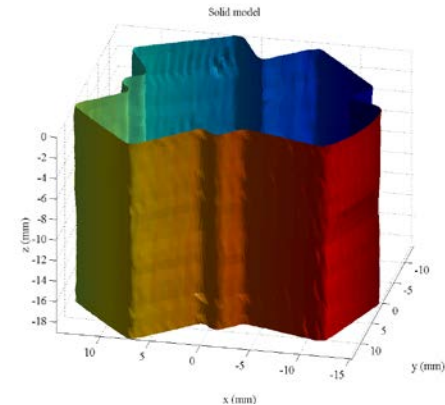
Wireframe



Reconstructed section



Rendered solid model

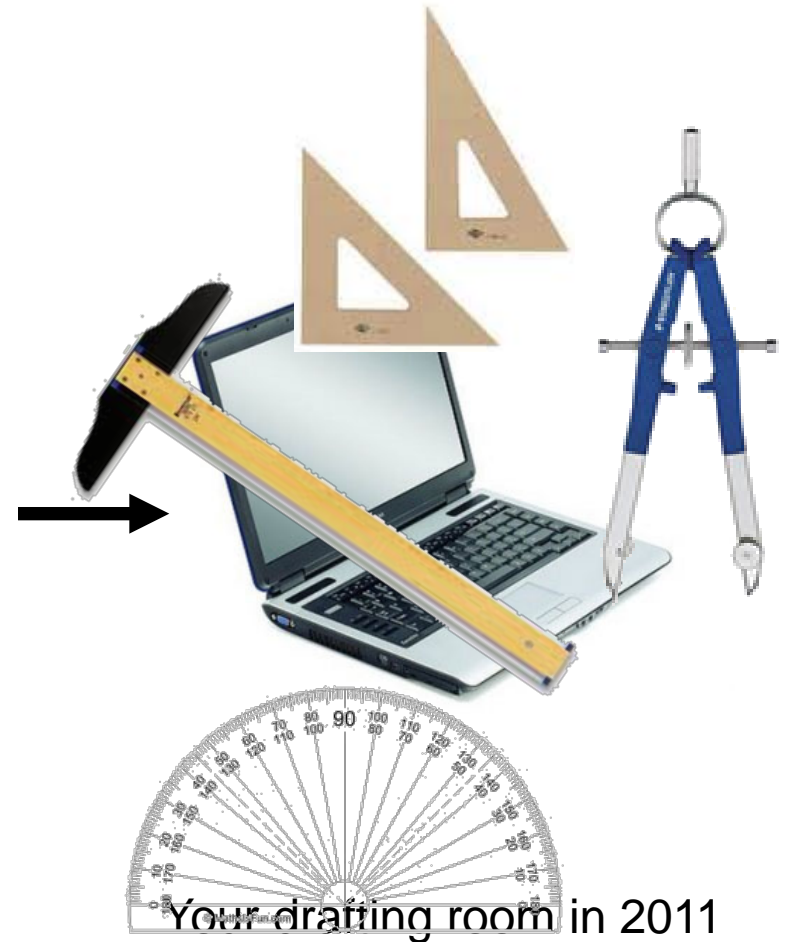


# Introduction to CAD

# Evolution of Drafting



A drafting room in the 1950s



Your drafting room in 2011

# Computer Aided Drafting (CAD)

- Replaced the drafting table
- Creating electronic drawings
- Can be used to create pictorial perspective, isometric, oblique, and orthographic drawings as well as electrical, pneumatic, hydraulic, and control system schematics
- Examples include **IntelliCAD** and **AutoCAD**

# Why do we need CAD?

- CAD is an effective way to communicate your ideas and designs
  - Used to produce working drawings
- Manufacturing is becoming more integrated, more global
- Systems are becoming more complex
- Working drawings are needed in all disciplines
  - Electrical, civil, mechanical, aerospace, manufacturing, architecture

# Why do we need CAD?

- 1960s – Lockheed SR-71
  - Supersonic reconnaissance aircraft
  - 30,000 hand-drafted working drawings!
    - Design changes required a lot of time
    - Filing and record keeping were challenging



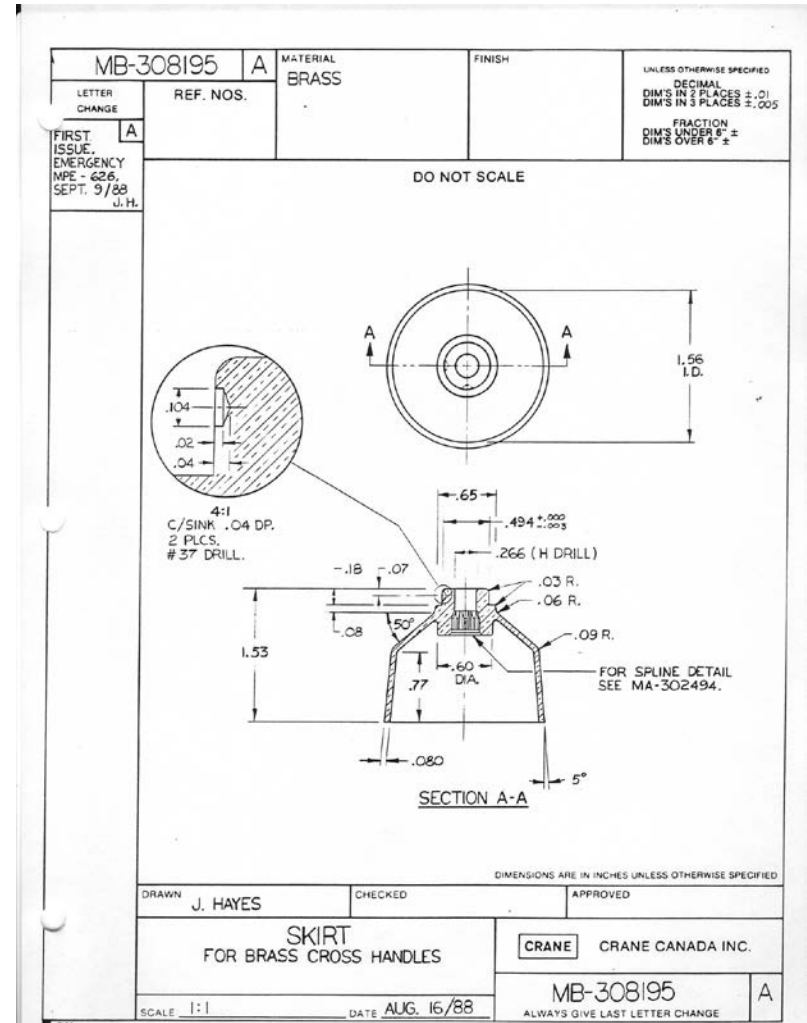
# Why do we need CAD?

- 2007 – Airbus A380
  - Modern, 500+ passenger commercial aircraft
  - Designed and manufactured in several countries
    - Approximately 500 suppliers
  - 1 global database
    - Database with solid models and CAD drawings
    - Automatically updated



# Computer Aided Drafting

- CAD is crucial in the detailed design stage
- Computer aided drafting enables modifications to be made with ease
- Compare this with hand drafting



# A Word On CAD

- CAD programs are very useful tools because most of them automatically follow the conventions discussed
- However, the designer is still responsible for ensuring the integrity of the drawing
  - CAD programs make mistakes, and sometimes the default options are not the most efficient way to convey the information

# CAD Advantages

- Increased accuracy
- Increased speed
- Easy revision
- Better design analysis
- Better presentation
- Libraries of drawing aids
- Improved filing

# When do we use CAD?

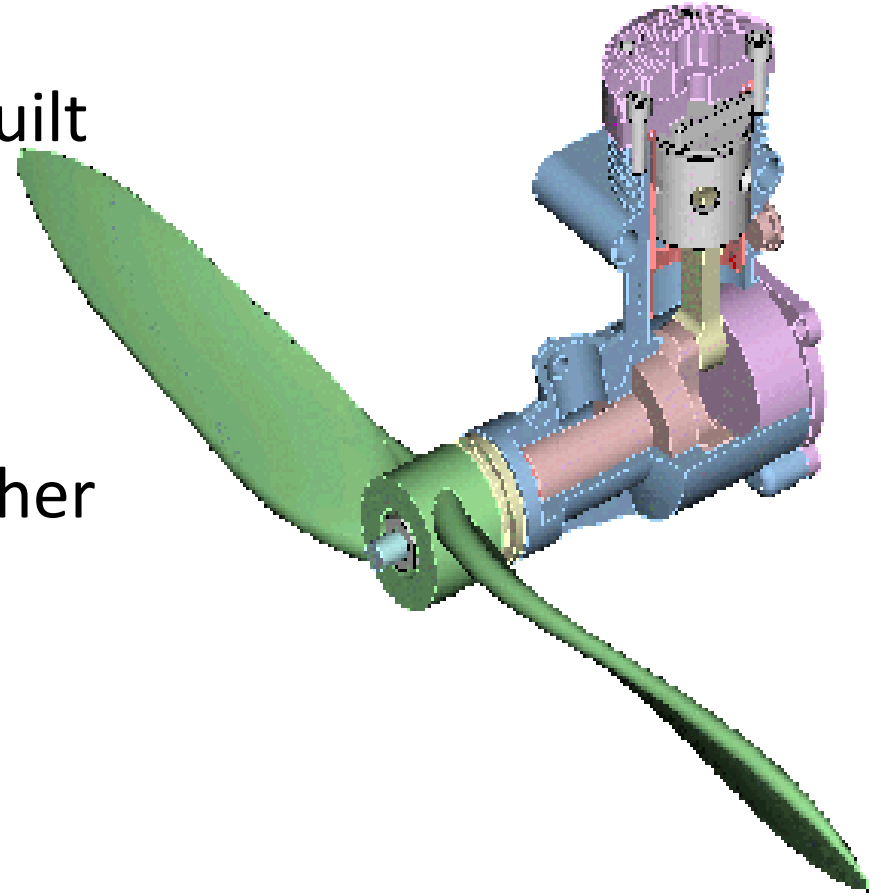
- When you want to clearly communicate a conceptual design
- When you want to machine a part
- When someone else is manufacturing or machining parts for you
  - Want to get exactly what you had in mind
  - Technologists and machinists need to be able to understand and interpret the design

# Engineering Computer Graphics

- The major areas of computer graphics are:
  - CAD: Computer-Aided Design
    - Used to solve design problems, analyze design data, store and disseminate design information
  - CADD: Computer-Aided Design Drafting
    - Using computers to generate engineering drawings and technical documents
  - CAD/CAM: Computer-Aided Design/ Computer-Aided Manufacturing
    - A computer based system used to design a product, devise the production steps, electronically transfer the data to control the manufacturing equipment
  - CIM: Computer-Integrated Manufacturing
    - A computer based system that coordinates and operates all stages of manufacturing from design to finished product

# Solid Modeling (Visualization)

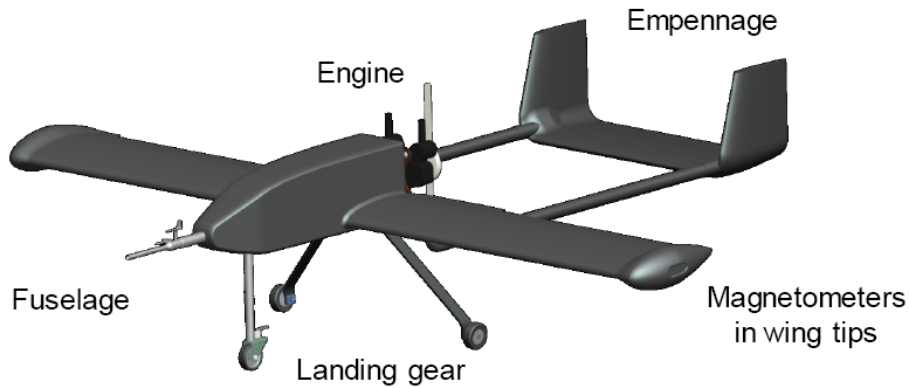
- Using a **solid modeler**, an entire prototype can be built and tested in a virtual environment before machining a single part
- Shows how parts fit together



# Solid Modeling

- The software creates 3D virtual objects
- The virtual objects appear as axonometric projections
- The models can be virtually manipulated, just like a physical object
- Example products include **Pro/ENGINEER** and **Solid Edge**

# Carleton GeoSurv II UAV Project



# CAD in ECOR 1010

- CAD is one of the many tools that you're learning this semester
  - Lab 2, lab 3, and the design project
- Won't become an expert in 4 months, so don't worry
  - You'll learn what the tools are and where to find them
  - Will develop a base that you can build on in future years
  - Will have many opportunities to use these skills at Carleton and in your careers as engineers

# CAD Software: IntelliCAD

- IntelliCAD can be used for report sketches, but it is really meant for technical drawing
- You should already be familiar with IntelliCAD (Lab 2)
  - The layout of the IntelliCAD environment
  - Basic drawing – lines, circles, etc.
  - Grid and snap features
  - Importing blocks
  - Creating text

# IntelliCAD and Pro/E Help

- On your own, go through the IntelliCAD primer slides (associated with Lecture 8)
  - on WebCT
- Read Chapter 15 and Pro/ENGINEER Tutorial in [Support Material](#) Folder in WebCT

# Design and CAD

- As a result of CAD, the design process has become much faster
- Although revolutionary, CAD has not taken over every aspect of drawing
- Freehand sketching is still important

# *Freehand Sketching*

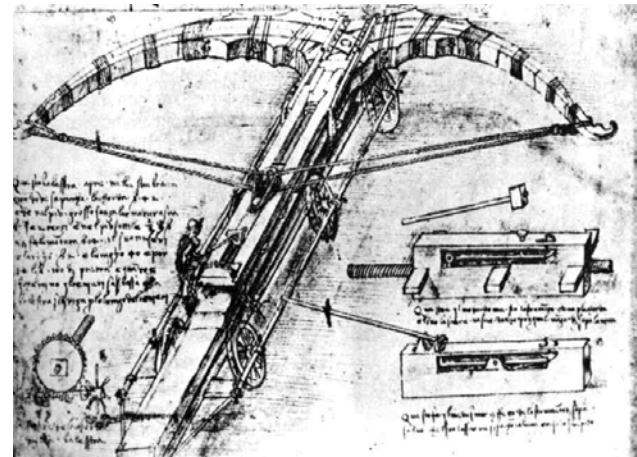
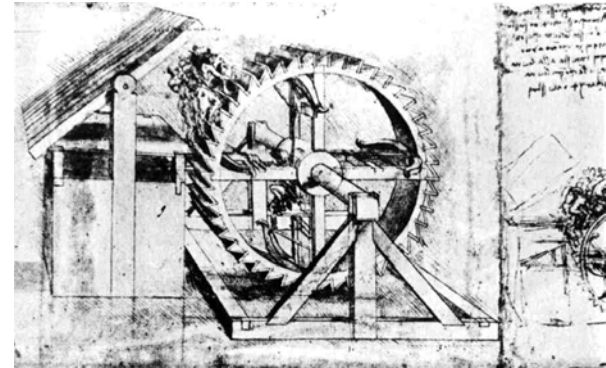
- **Freehand sketch:** drawing created without the use of a straightedge or other aids
- Used in the early stages of design
  - Ideas sketched on a napkin or notepad
- Outperforms CAD when a fast sketch is needed
- Not intended to be used as a technical drawing for manufacturing a part

# Visualization

- Being able to visualize in 3D is key
- Thought experiment:
  - Close your eyes and picture any object floating in mid-air ... Now rotate the object in your mind ... Imagine looking at it from every angle and direction
- This ability is crucial when creating graphical representations of real objects

# Sketching

- Sketching is *freehand* drawing without the use of instruments such as a straightedge, compass, or drawing templates
- Sketching is a key means of engineering communication
- Sketches are used to develop ideas and make decisions about how to solve a problem
- Many new projects and products begin as sketches made on the back of an envelope, or on a napkin in a restaurant, hockey game, airplane ...

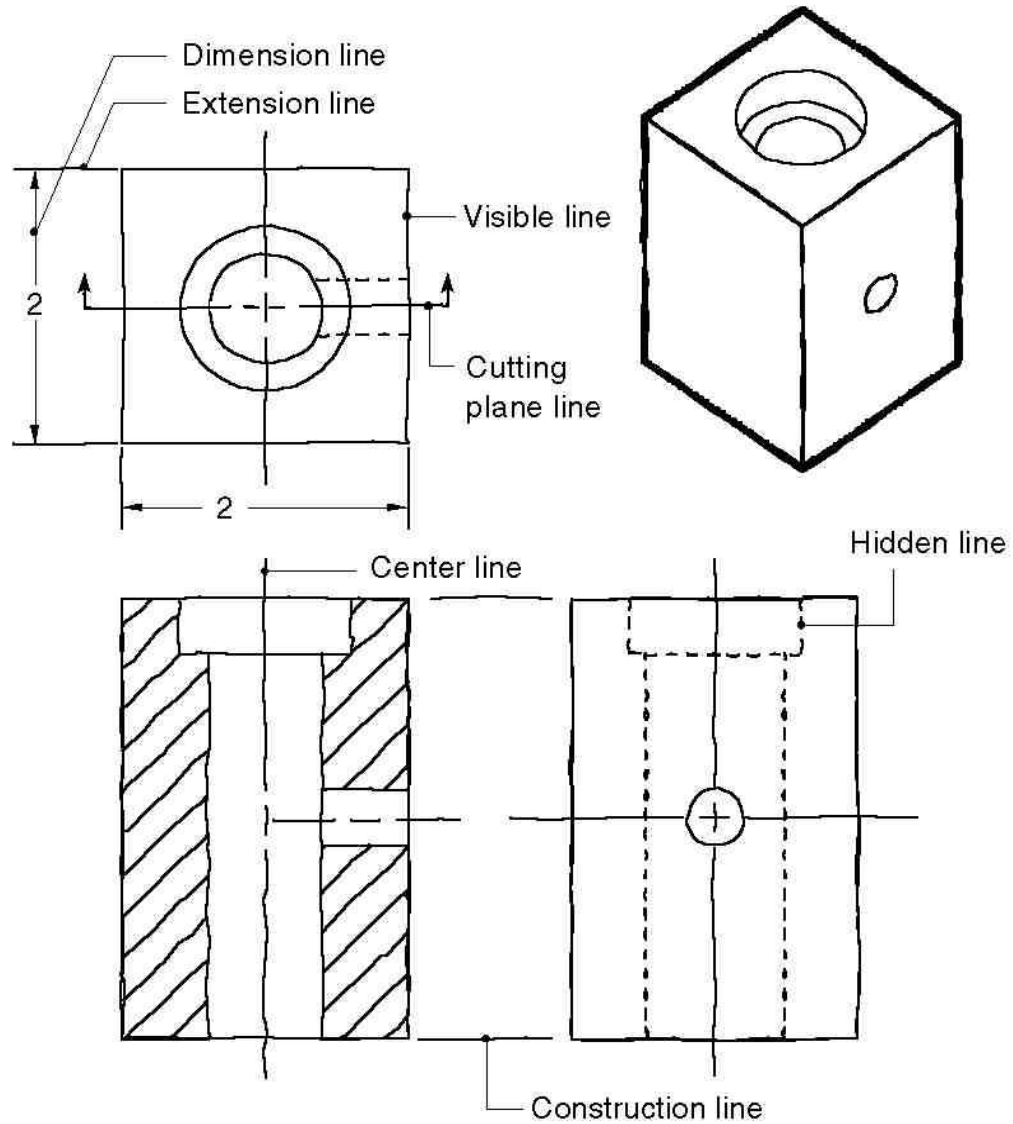




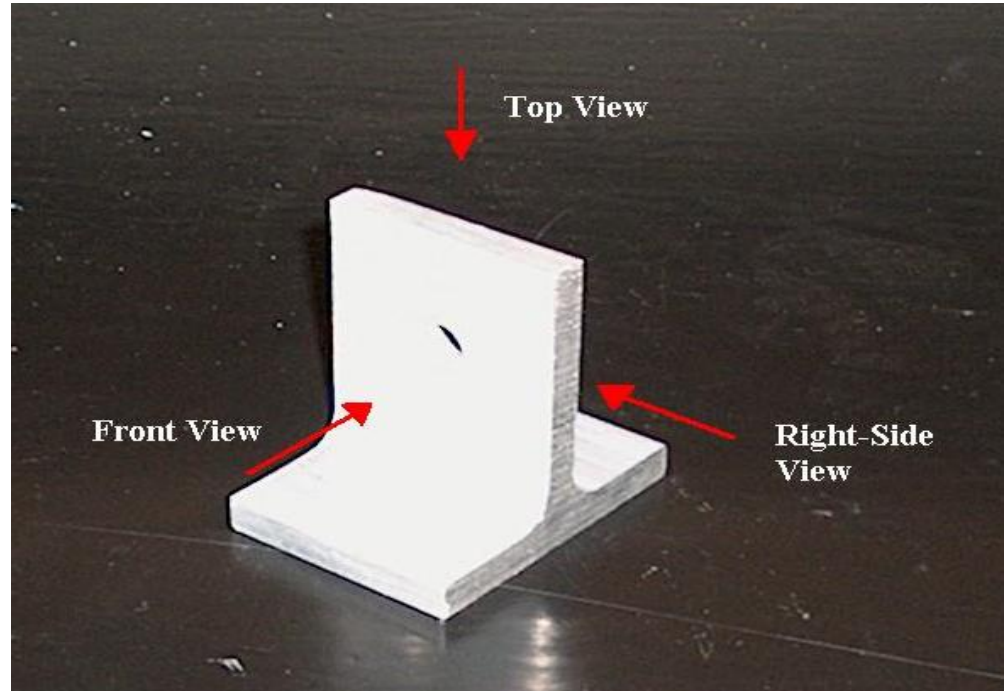
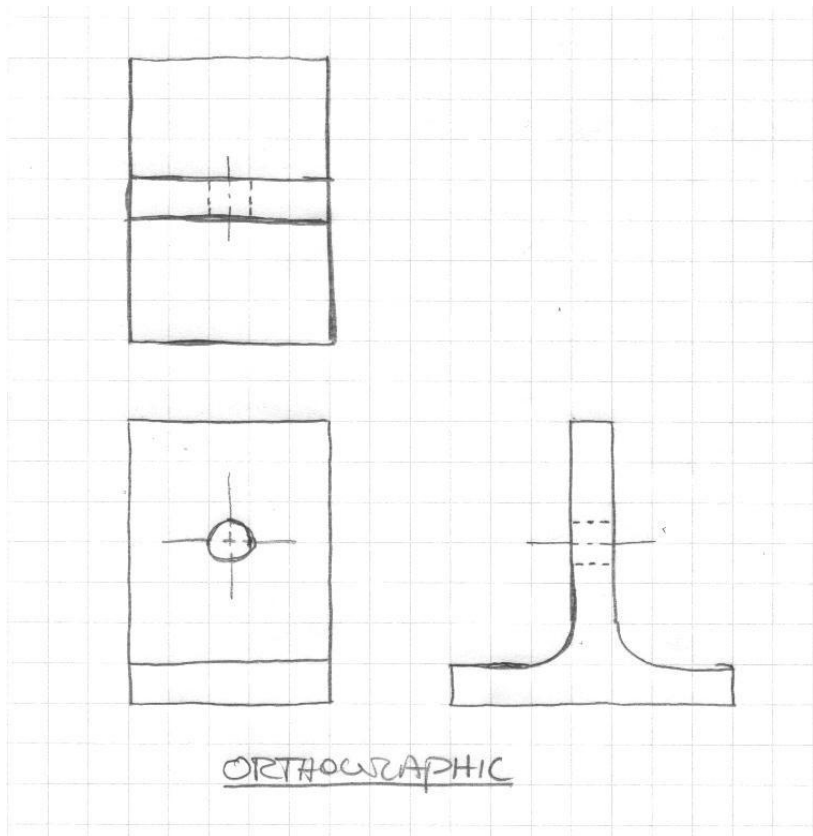
# Hand Sketching Tips

- Use one stroke when drawing a line – don't lift pencil off paper
- For long lines, keep your eyes focused on where the line is going to end
- Use construction lines – very faint lines that outline an object
- For circles, use a square construction square and then draw the inscribing circle

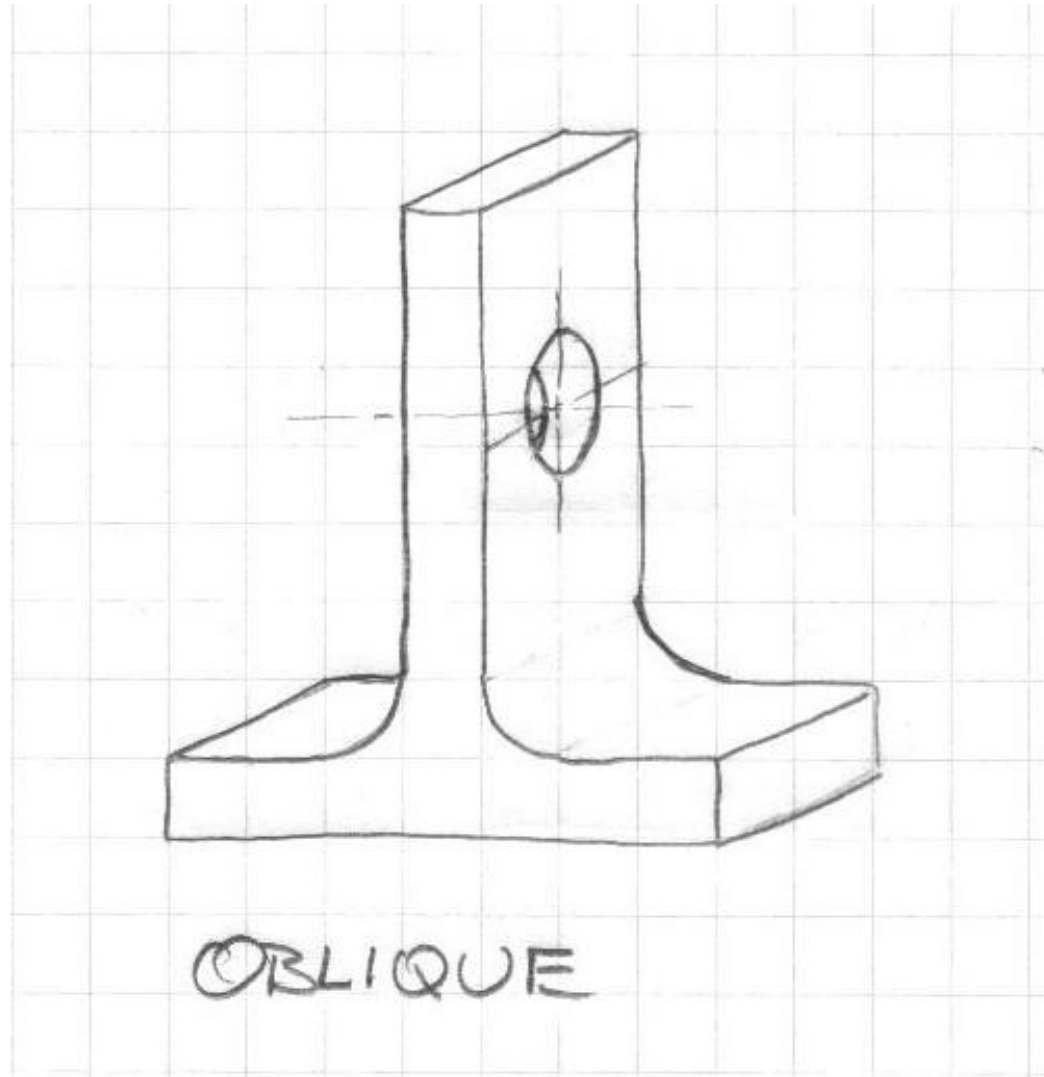
# Sketching Example



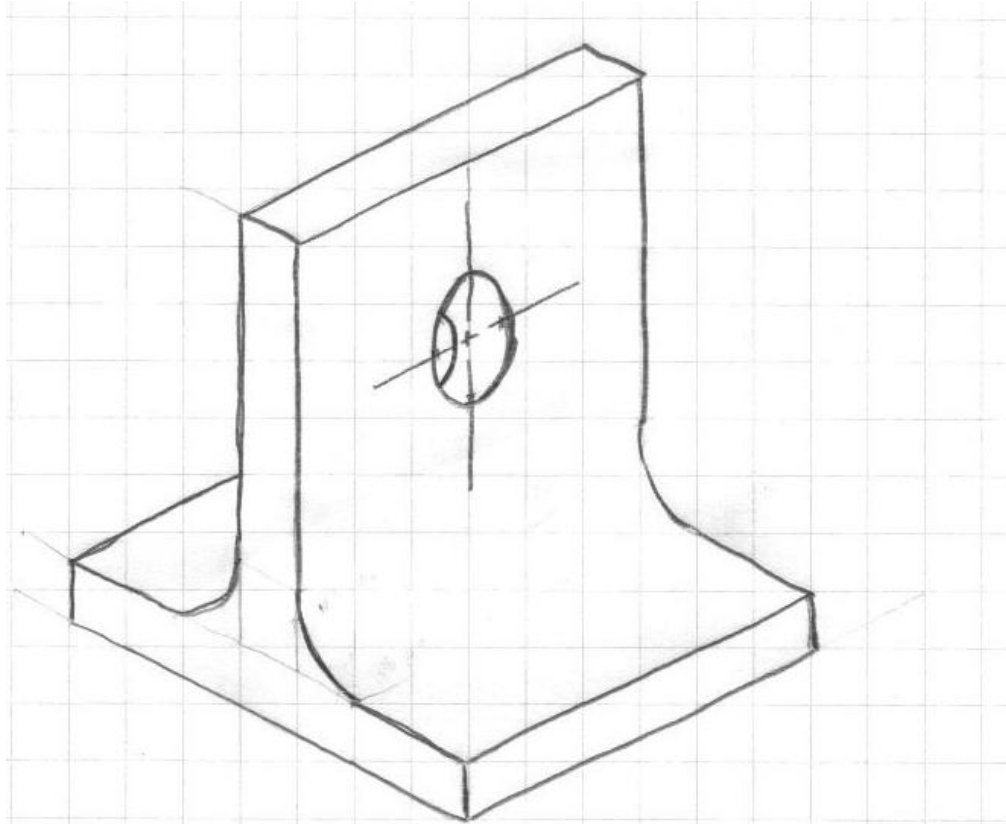
# Orthographic Sketching



# Oblique Sketching

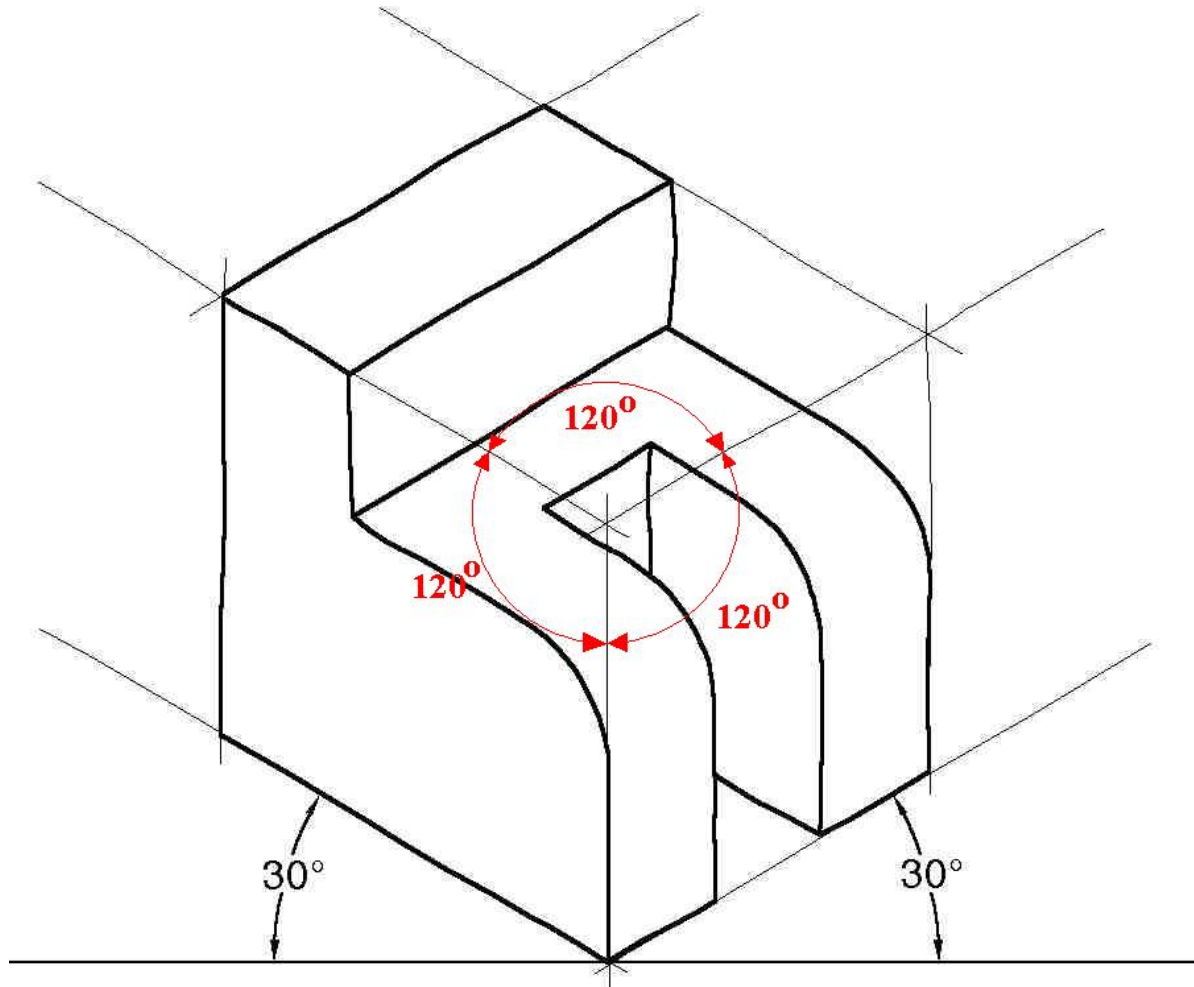


# Axonometric Sketching

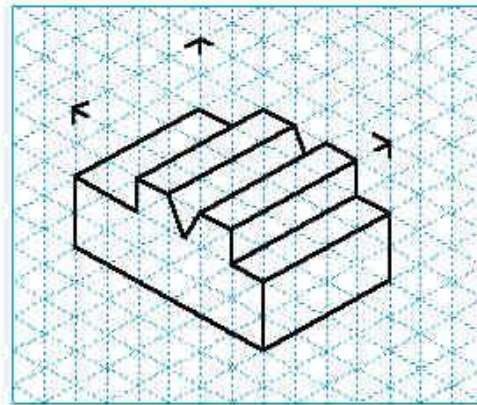
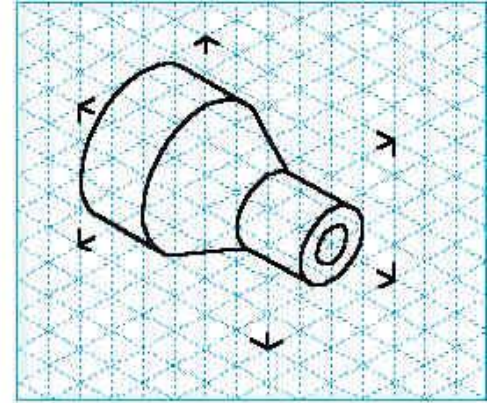
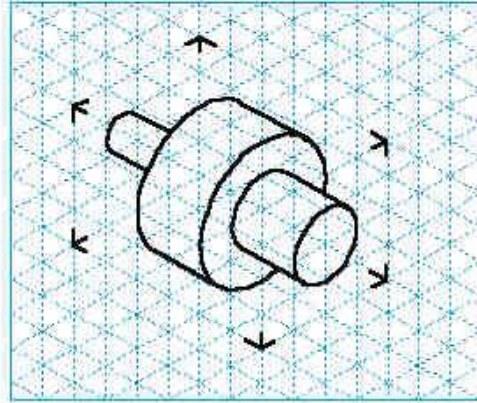
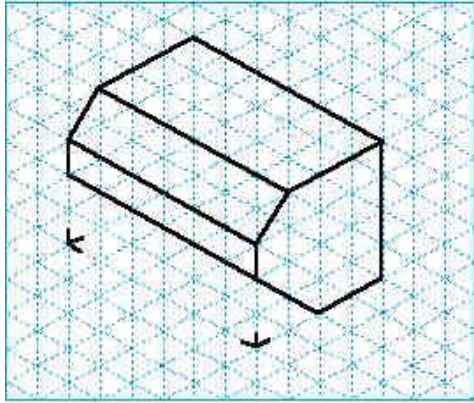


AXONOMETRIC  
(APPROXIMATELY ISOMETRIC)

# Isometric Sketching



# Isometric Sketch Paper



# Reading Assignment

- You should have read Chapters 12 to 14 already.
- For next lecture Read Chapters 15 & 16.