

2.000 How and Why Machines Work, Lecture # 2

Today in 2.000

- ⊙ Camera discussion
- ⊙ Units and reason
- ⊙ Engineering flow balances
- ⊙ Sketching
- ⊙ Project management (discussion)
- ⊙ Homework #2

CAMERA DISCUSSION

Progress

Problems

UNITS AND REASON

No one will pay you to invent things that aren't practical

Reasonable answers

You must be able to tell if an answer is reasonable

How do you do this?

- ⊙ Understand magnitudes
- ⊙ Compare with magnitudes which are similar or familiar
- ⊙ Think of worst/best case scenarios and compare

These are rough approximations!!

⊙ Force

- ✓ Q: What is a lbf? A: ~ loaf of bread
- ✓ Q: What is a Newton? A: ~ a large apple or small grape fruit
- ✓ Q: What is a ton (2000 lbf?) A: ~ a medium to large sized truck

⊙ Pressure

- ✓ Q: What is 1 psi? A: ~ loaf of bread distributed over a quarter
- ✓ Q: What is a Pa? A: ~ an apple distributed over 1 square meter
- ✓ Q: What is 40 000 psi? A: ~ 20 medium sized trucks on a quarter!

⊙ Power & Energy

- ✓ Q: What is 1 hp? A: Athlete can sustain (for a short time) ~1/4 - 1/3 hp
- ✓ Q: What is a Watt? A: Average light bulb is 60 - 100 Watts

⊙ Torque

- ✓ Q: What is a ft-lbf? A: ~ loaf of bread hung from a 12 inch ruler
- ✓ Q: What is a N-m A: ~ an apple hung from the end of a meter stick

Variables and units you will use in 2.000

Common units you will use/see in 2.000

Variable	Name	English Units	Metric Units
E	Energy	[ft-lbf]	[J] or [N-m]
T	Torque	[ft-lbf or in-lbf]	[N-m]
ω	Angular speed	[rpm or rad/s]	[rad/s]
θ	Angle	[radian]	[radian]
F	Force	[lbf]	[N]
x	Distance	[ft or in]	[m]
A	X-sectional area	[in² or ft²]	[m²]
Δp	Pressure change	[psi]	[Pa]
Q	Volume flow rate	[in³/s or ft³/s]	[m³/s]
v	Velocity	[in/s or ft/s]	[m/s]
V	Voltage	Volts	Volts
I	Current	Amps	Amps
R	Resistance	Ohms	Ohms

BALANCES

Flow balances

If the behavior of flow (B) is deterministic we can model the flow:

- ⊙ $\Sigma B_{in} = \Sigma B_{out} + \Sigma B_{stored}$
- ⊙ Many engineering analyses are based on flows
- ⊙ The key issue: you should think - after = before + change

Examples of flows “B”

- ⊙ Mass
- ⊙ Energy
- ⊙ Momentum

To use flow balances, we need to have:

- ⊙ Understand the flow and derivative variables
- ⊙ Physics that characterize the flow
- ⊙ Working coordinate system (directions of flows are important)
- ⊙ Understand control volume (CV) and mass volume (MV)
- ⊙ Provide proper placement of a control volume (CV) that simplifies analysis

Flow balances we will use with control volumes

Mass (m)

$$\Sigma m_{in} = \Sigma m_{out} + \Sigma m_{stored} \longrightarrow \frac{d}{dt}(\Sigma m_{in}) = \frac{d}{dt}(\Sigma m_{out} + \Sigma m_{stored}) \longrightarrow \Sigma \dot{m}_{in} = \Sigma \dot{m}_{out} + \frac{d}{dt} m_{stored}$$

Momentum (M)

$$\vec{M}_{in} = \vec{M}_{out} + \vec{M}_{stored} \longrightarrow \Sigma(m_{in} \vec{v}_{in}) = \Sigma(m_{out} \vec{v}_{out}) + \Sigma(m_{system} \vec{v}_{system})$$

$$\text{Momentum} \longrightarrow \left[\frac{d \Sigma(m_{in})}{dt} \cdot \vec{v}_{in} \right] + \Sigma \vec{F} = \left[\frac{d \Sigma(m_{out})}{dt} \cdot \vec{v}_{out} \right] + \frac{d (m_{system} \cdot \vec{v}_{system})}{dt}$$

Energy (E)

$$\Sigma E_{in} = \Sigma E_{out} + \Sigma E_{stored}$$

$$\frac{d}{dt}(\Sigma E_{in}) = \frac{d}{dt}(\Sigma E_{out} + \Sigma E_{stored}) \longrightarrow \Sigma P_{in} = \Sigma P_{out} + \Sigma \left(\frac{d E_{stored}}{dt} \right)$$

Characteristics of control volumes

CVs are artificial boundaries used to simplify analysis

- ⊙ Many fundamental engineering relationships can be derived using CVs

Control volumes (CVs) have “porous” surfaces: control surface (CS):

CVs have “solid” characteristics

- ⊙ Forces may act upon CV boundary
- ⊙ Forces may be exerted by CV boundaries

CV can have different shapes

- ⊙ **Fixed control volume**
 - ✓ Do not change position (relative to our working coordinate system) or shape with time
 - ✓ Often (but not always) used when flow pathways are static
- ⊙ **Moving control volume**
 - ✓ May change position (relative to our working coordinate system) or shape with time
 - ✓ Often (but not always) used when flow pathways are changing shapes

Using control volumes

1. Pick reference coordinate system to simplify analysis

- ⊙ Usually aligned/perpendicular to flows
- ⊙ Must use inertial reference frames for momentum flow

2. Place boundaries to your advantage (may cut through anything)

- ⊙ Where you **know** what is going on (known variables)
- ⊙ Where you **want to** know what is going on (unknown variables)

3. Orient boundaries (**||** and **⊥** to flows) to simplify analysis

4. Draft flow balance equations for rough equations

5. Use physics to fill in details of balance equation

6. Solve equations

What you need to know about control volumes

What you will learn/be required to do:

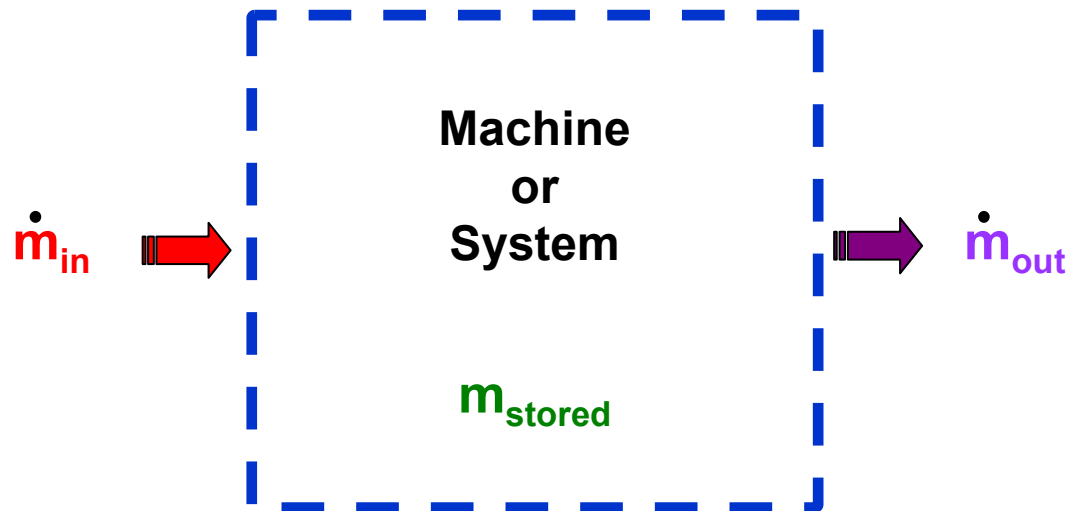
- ⊙ **Draw control volumes with proper boundaries**
- ⊙ **Does material along the boundary**
 - ✓ Belong inside the CV
 - ✓ Belong outside the CV
- ⊙ **Utilize them in machine analysis**

Mass balance in machines

Understanding and utilizing mass balance is important

- ⊙ mass carries momentum and energy.

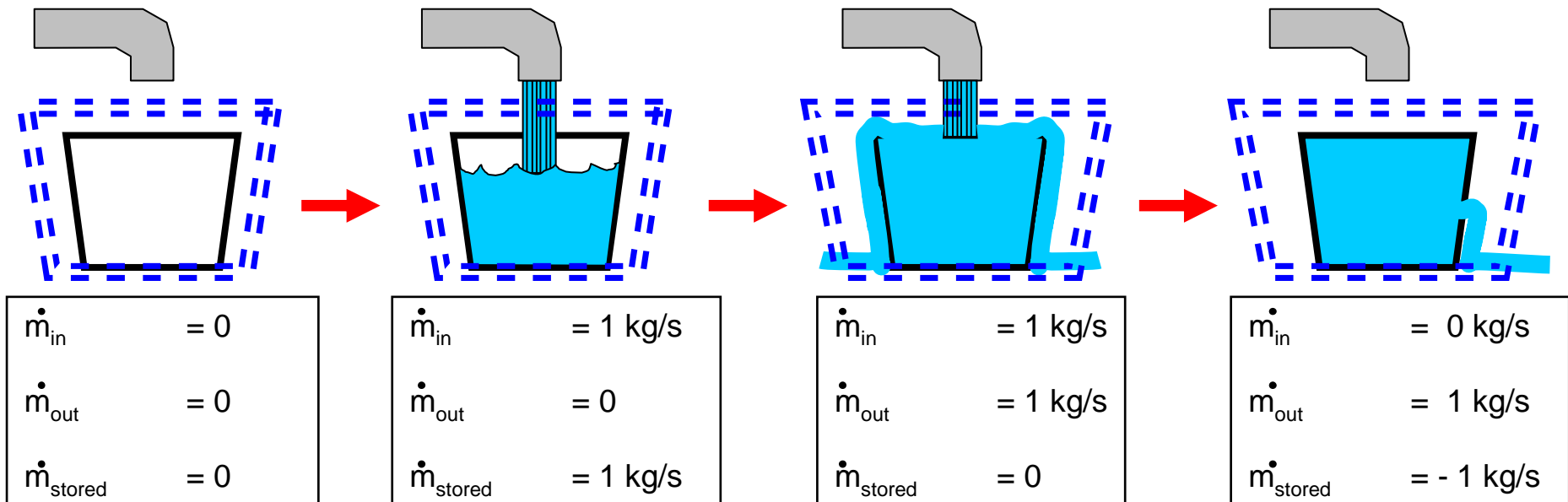
$$\sum \dot{m}_{in} = \sum \dot{m}_{out} + \frac{d(m_{stored})}{dt}$$



Example: Mass balance

Example: Filling a glass with a faucet

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} + \frac{d}{dt} m_{stored}$$



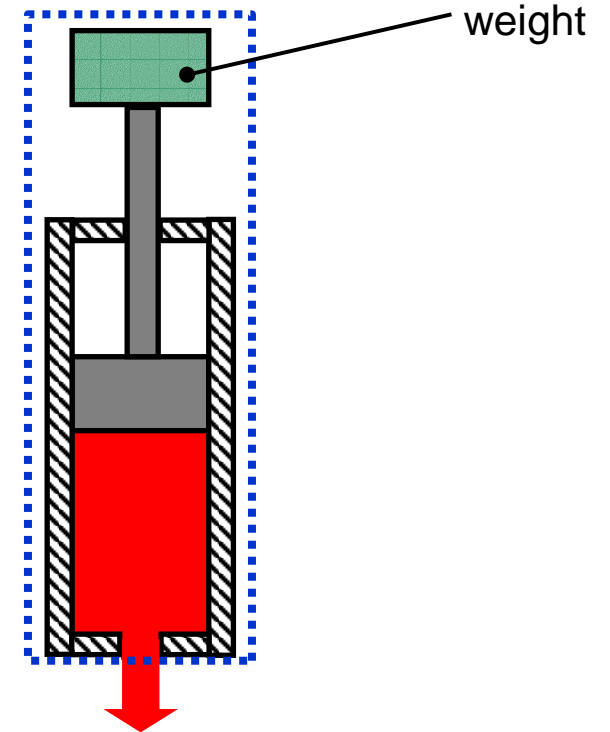
Example: Mass balance

Example: Hydraulic cylinder (CV = static geometry)

- CV encompasses cylinder, does not move

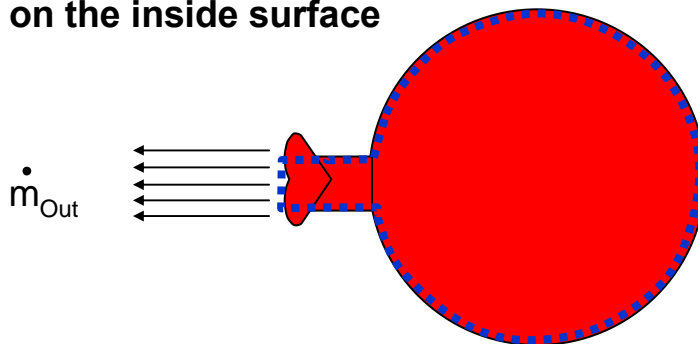
$$\Sigma \dot{m}_{in} = \Sigma \dot{m}_{out} + \frac{d}{dt} m_{stored}$$

\dot{m}_{in}	=	0
\dot{m}_{out}	=	10 kg/s
$d(m_{stored})/dt$	=	- 10 kg/s



Example: Balloon (CV = varying geometry)

- CV resides on the inside surface



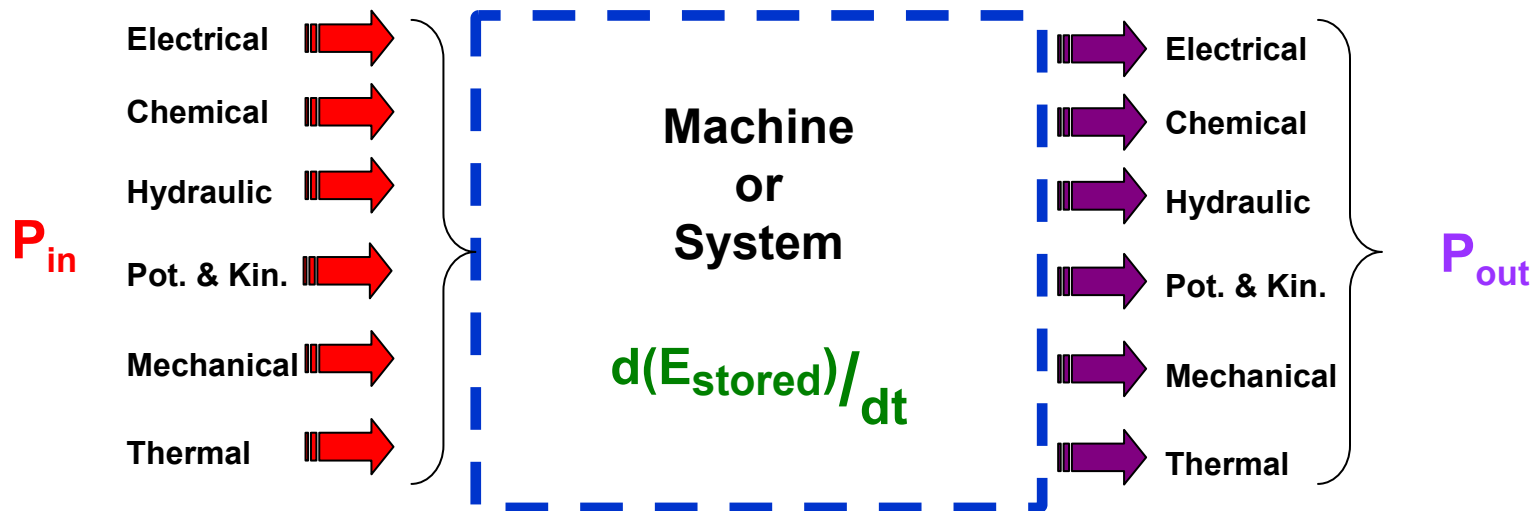
\dot{m}_{in}	=	0
\dot{m}_{out}	=	f(t)
$d(m_{stored})/dt$	=	- f(t)

Energy and power balance in machines

$$\Sigma \mathbf{E}_{in} = \Sigma \mathbf{E}_{out} + \Sigma \mathbf{E}_{stored}$$

$$P = \frac{dE}{dt}$$

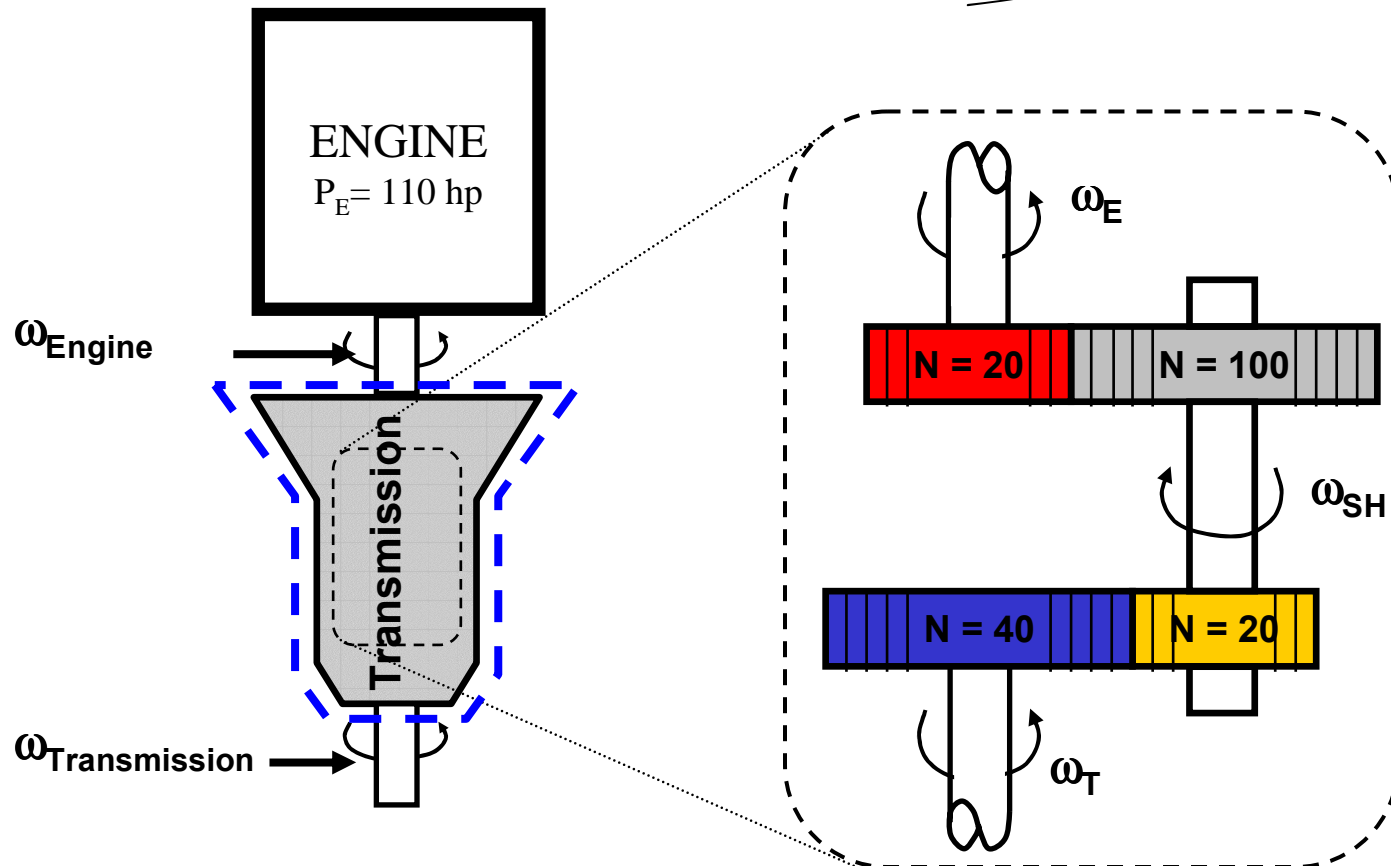
$$\Sigma \mathbf{P}_{in} = \Sigma \mathbf{P}_{out} + \Sigma \frac{d(\mathbf{E}_{stored})}{dt}$$



Example: Car engine-transmission

$$\sum \mathbf{P}_{in} = \sum \mathbf{P}_{out} + \sum \frac{d(E_{stored})}{dt}$$

$$\sum \mathbf{T}_E \omega_E = \sum \mathbf{T}_E \omega_E + \sum \frac{d(E_{stored})}{dt} \rightarrow 0$$



Momentum flow

Important!!!:

- ⊙ **An inertial frame is one in which Newton's First Law is valid, i.e. one in which an object free of external influence continues in its state of rest or uniform motion in a straight line.**

- ⊙ **Inertial frames moves at a constant velocity with respect to other inertial frames.**

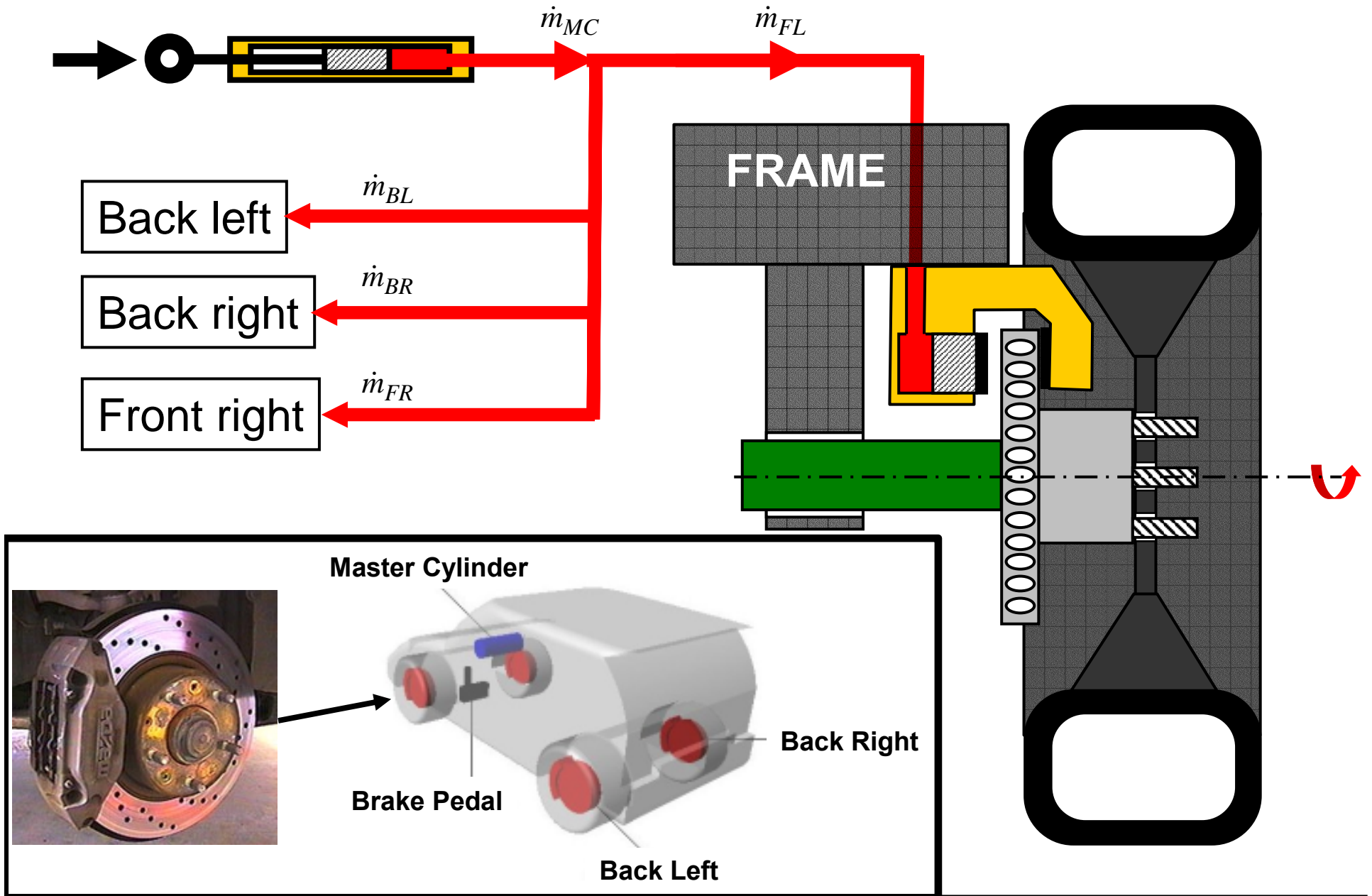
Simple example: Automotive braking system

Need: Speed of caliper pistons as a function of Master Cylinder piston

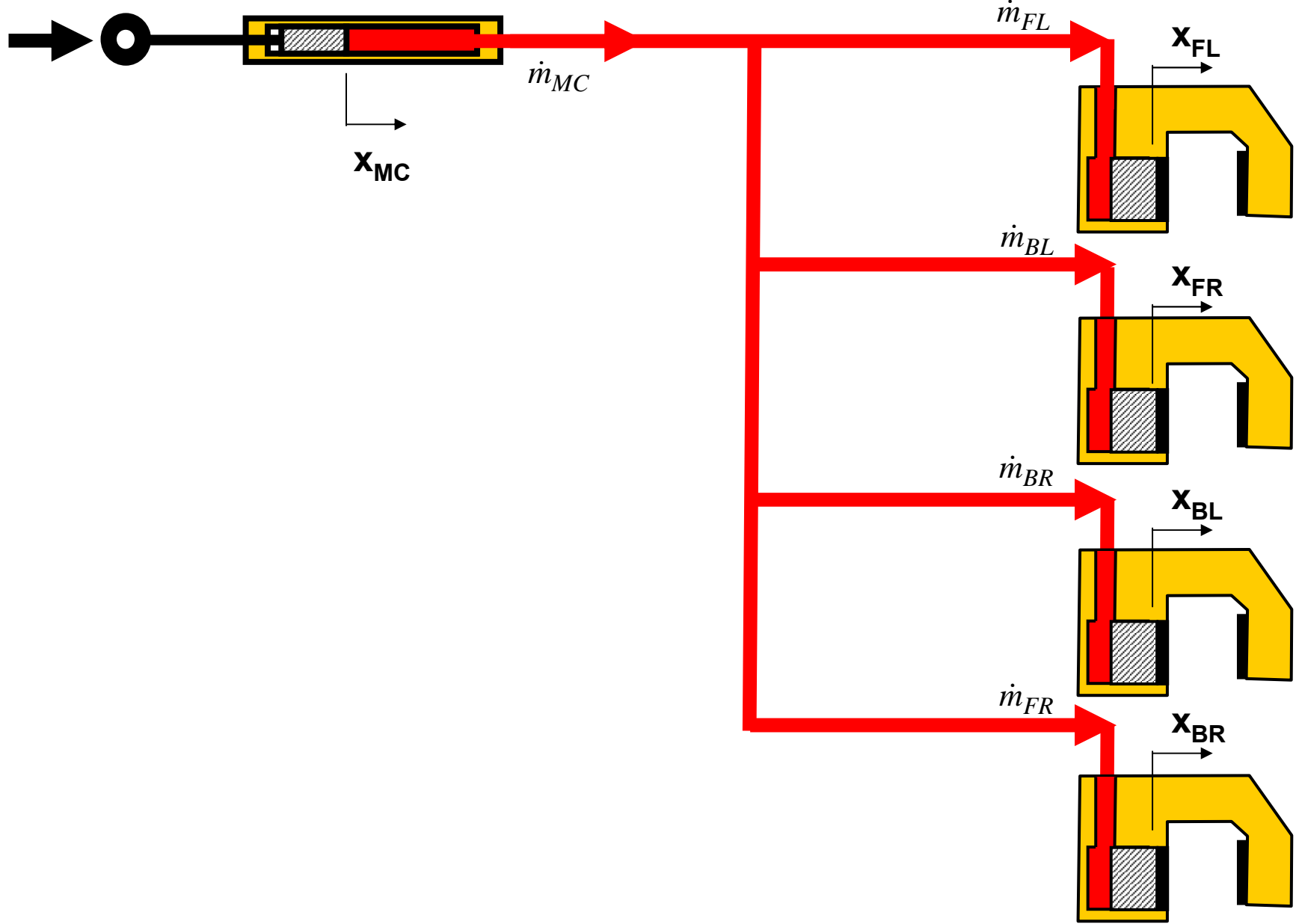
Given:

- ⊙ **Cross sectional areas of pistons (A_0, A_1, A_2, A_3, A_4)**
- ⊙ **Brake fluid is incompressible (Does not change volume when compressed)**
- ⊙ **By design, the front caliper pistons move $\frac{1}{2}$ speed of the rear pistons**

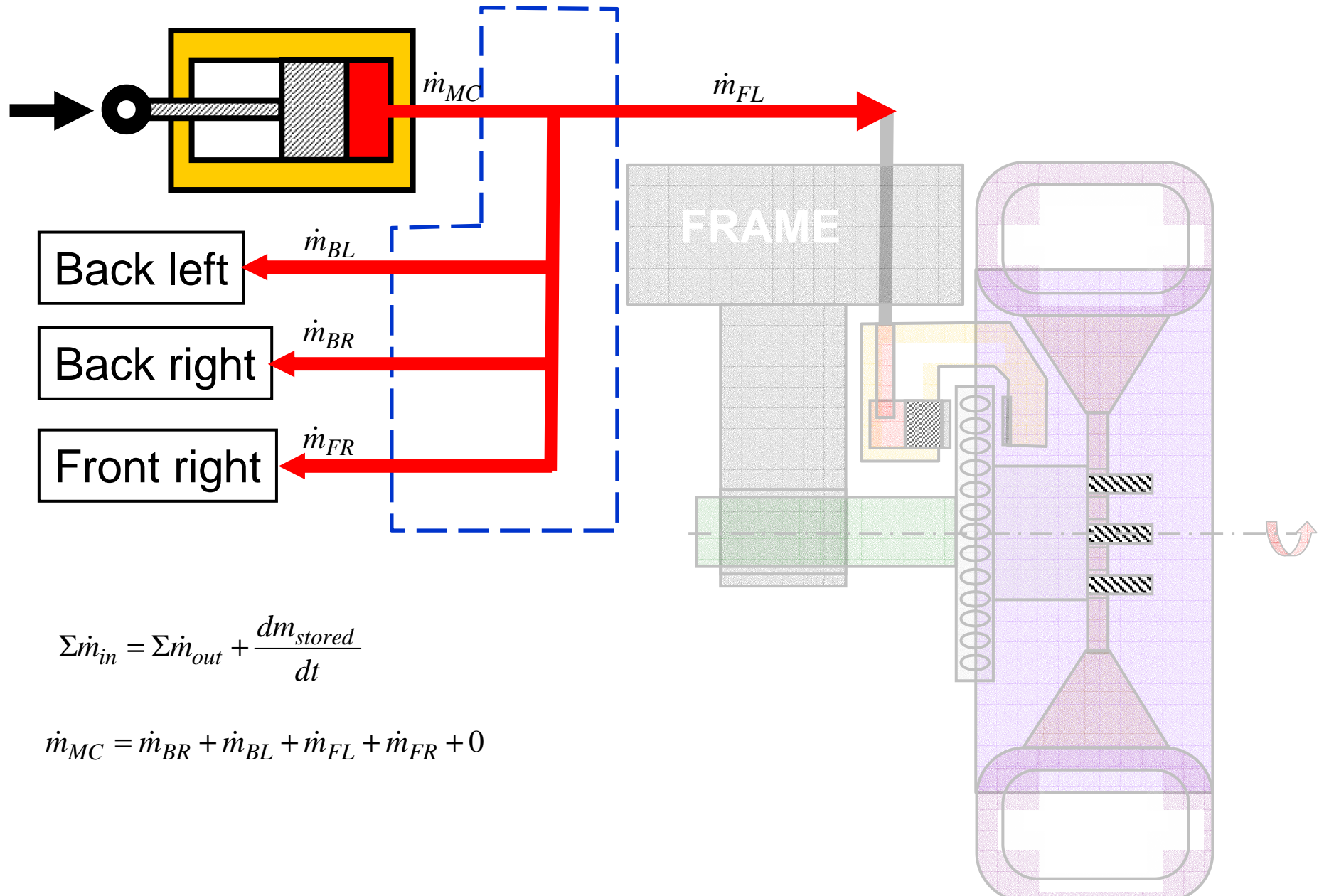
Automotive braking system: Mass flow



Example: Automotive braking system



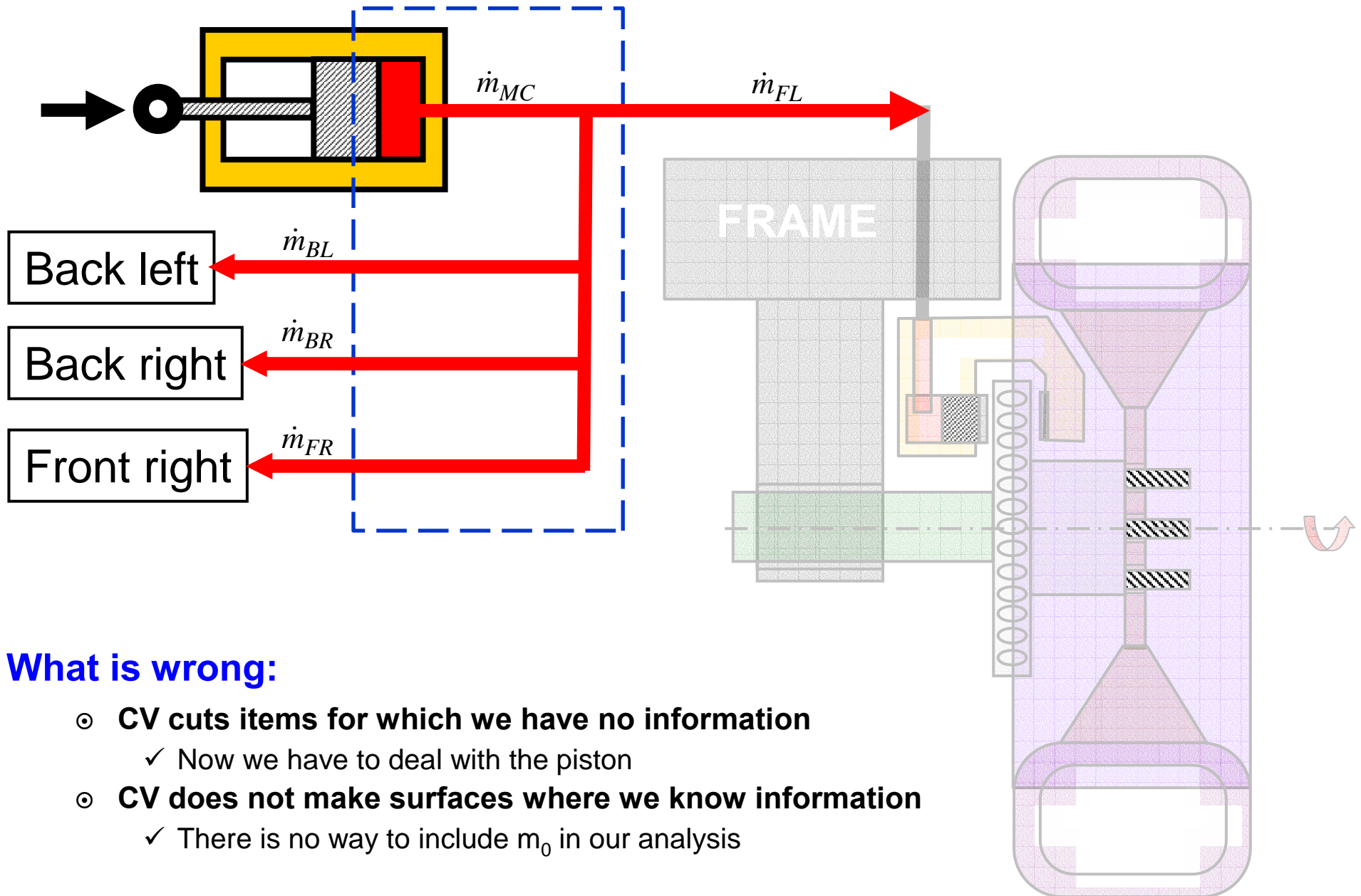
Example: Automotive braking system



$$\Sigma \dot{m}_{in} = \Sigma \dot{m}_{out} + \frac{dm_{stored}}{dt}$$

$$\dot{m}_{MC} = \dot{m}_{BR} + \dot{m}_{BL} + \dot{m}_{FL} + \dot{m}_{FR} + 0$$

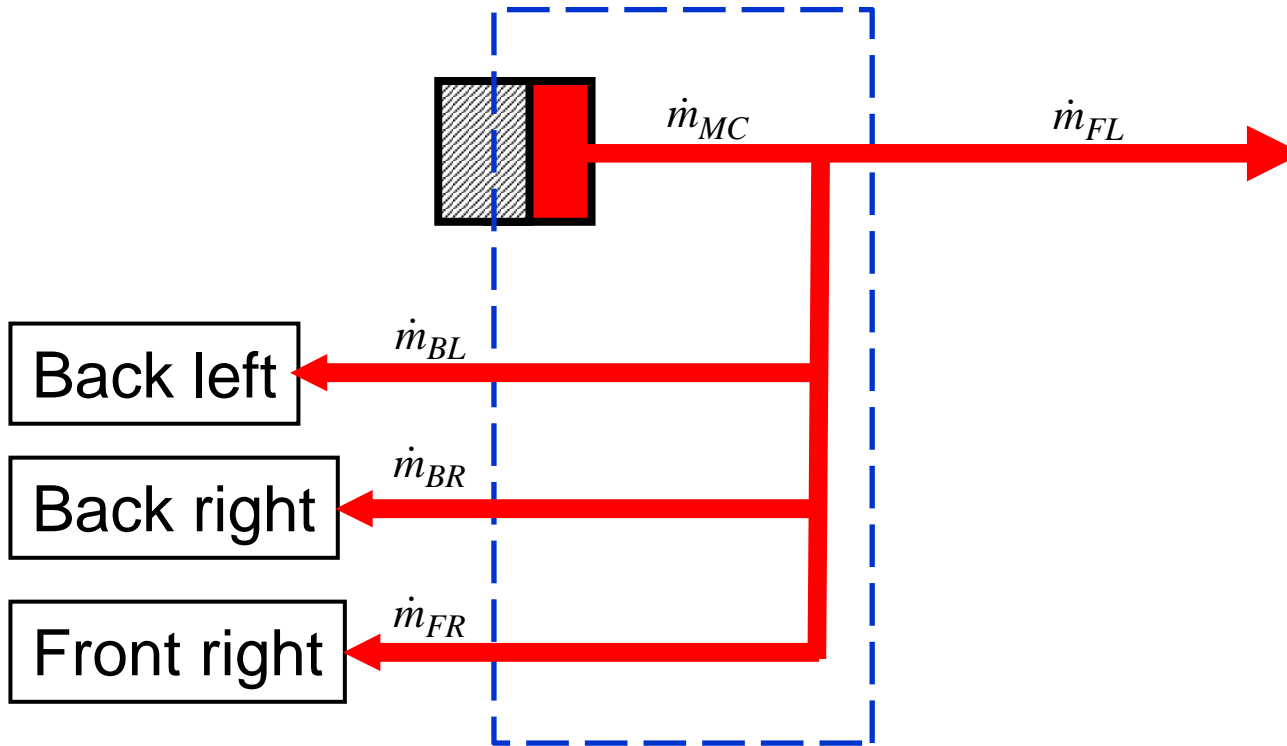
The wrong way: Automotive braking system



What is wrong:

- ⊙ **CV cuts items for which we have no information**
 - ✓ Now we have to deal with the piston
- ⊙ **CV does not make surfaces where we know information**
 - ✓ There is no way to include m_0 in our analysis

The wrong way: Automotive braking system



One can show is \dot{m}_{MC}

$$\Sigma \dot{m}_{in} = \Sigma \dot{m}_{out} + \frac{d}{dt} m_{stored}$$

$$\dot{m}_{piston} = \dot{m}_{BR} + \dot{m}_{BL} + \dot{m}_{FL} + \dot{m}_{FR} + (\dot{m}_{piston} - \dot{m}_{fluid-decrease})$$

Eventually get same answer, but complicates this analysis
Drawing the wrong CV can also make it impossible to solve a problem

ASSIGNMENT 2

Resume

Job Sign-up (Internship on Links)

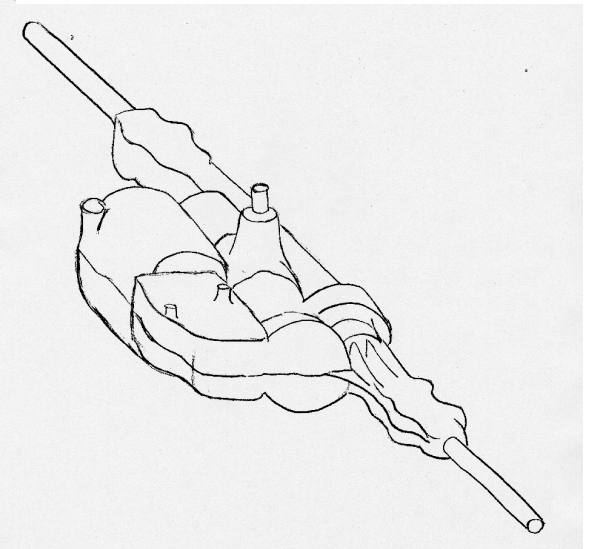
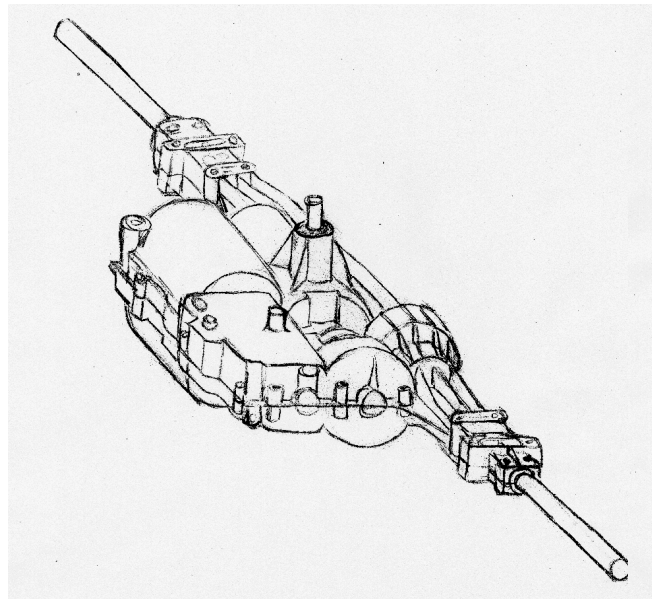
Read Cad I Tutorial Reading

Download/install CAD software (optional)

Bring \$40 to Lab if you want a CAD text book

VISUAL COMMUNICATION: SKETCHING

Make sure to get a sketching handout at the front
of the class or from the web



Why you need to know what and how to sketch

Career

- ⊙ Industry says engineers can't communicate.
- ⊙ If you can't communicate your ideas, you'll be working at Super Burger.

Visual communication is universal:

- ⊙ Anyone who can see has the potential to understand
- ⊙ Understanding is limited by the sketcher's ability

Who ever made anything without sketching it first? Examples:

- ⊙ Thermo-nuclear bomb
- ⊙ Television
- ⊙ Safety pin

Sketching is the fastest and most mobile form of visual communication

It can make or break your success

What Is important & how to start

Two components of sketching

- ⊙ Knowledge (terminology, what is important)
 - ⊙ Skill/practice
- Today's lecture content
Practice, practice, practice

What is important? Basis for grading 2.000 sketching

- ⊙ Size (yes, size matters)
- ⊙ Proportion
- ⊙ Likeness
- ⊙ Necessary notes/explanation

Sketching and CAD are rough-fine processes

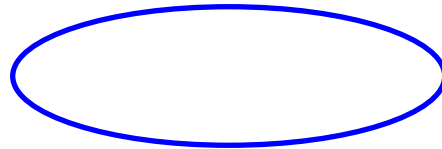
- ⊙ **ROUGH:** Lightly sketch outlines of major shapes (PRIMITIVES)
- ⊙ **FINE:** Sketch in outlines of minor shapes primitive
 - ✓ Determine what stays and what goes
 - ✓ Trace over guide/construction lines in bold
 - ✓ Add fine detail

Sketching basics - Primitives

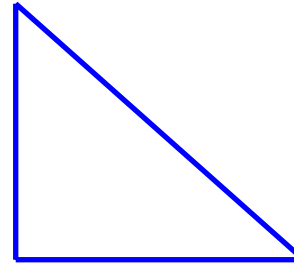
2D Sketch of primitive's characteristic shape



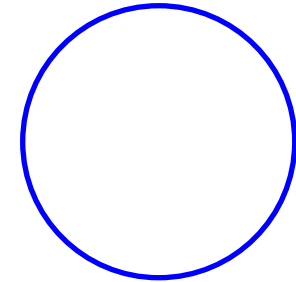
CUBE



CONE

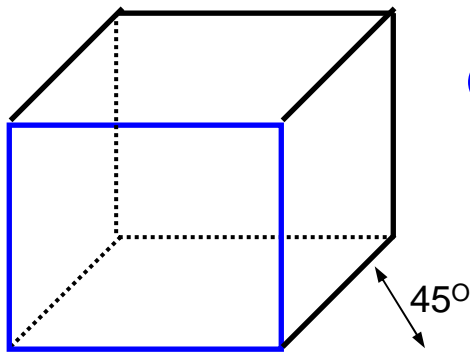


WEDGE

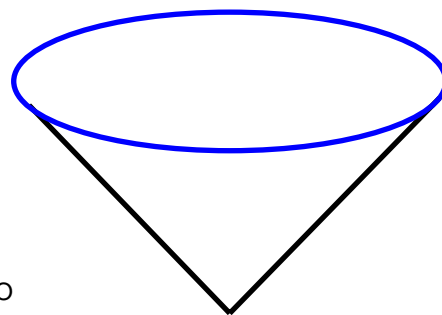


CYLINDER

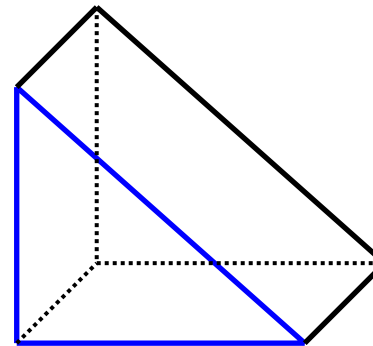
Primitives: 3D Extrusion



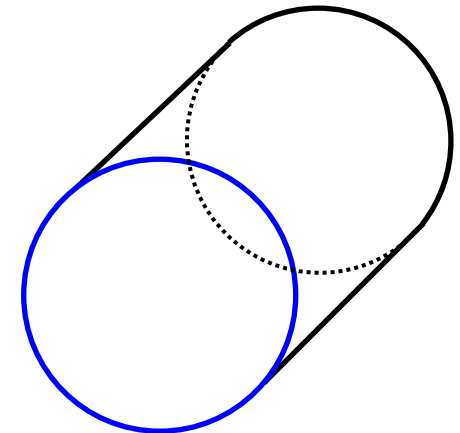
CUBE



CONE*



WEDGE



CYLINDER

Before You Start

Before you start, have a plan

Determine:

- ⊙ **PURPOSE PURPOSE PURPOSE**
- ⊙ **What is sufficient and necessary to do the job [I am not into art]**
- ⊙ **Audience & knowledge level**
- ⊙ **Technical or Non-technical**
- ⊙ **Familiarity**

Level of detail

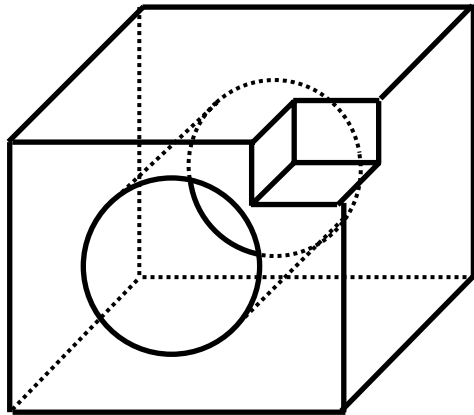
- ⊙ **Number and complexity of curves/lines**
- ⊙ **Shading / color**
- ⊙ **Decide on 2D or 3D**

Identify the major primitives/shape(s)

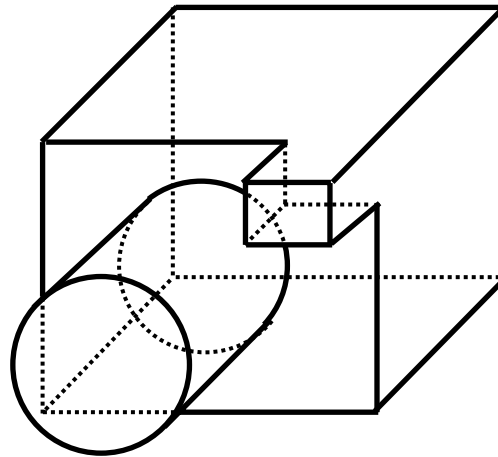
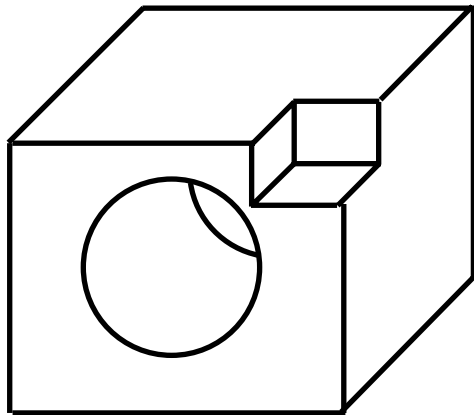
Sketching basics & terminology: Boolean sketches

Draw major primitives, use their surfaces for other sketches

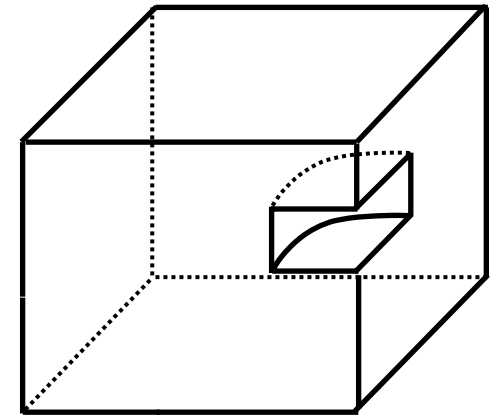
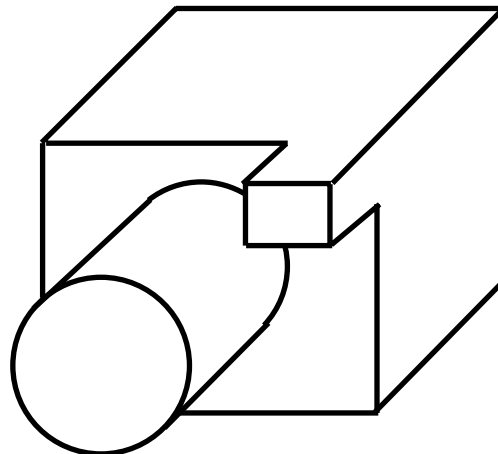
Extrude/cut/revolve the 2D sketch to make new features



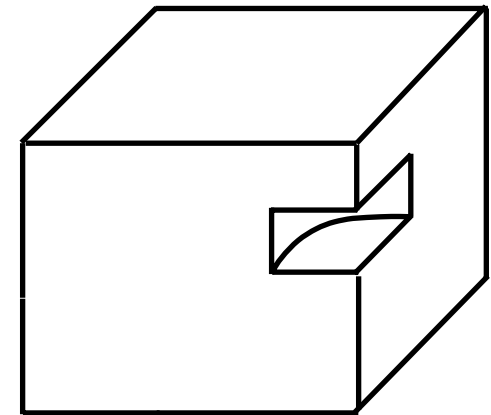
Extrude Cut



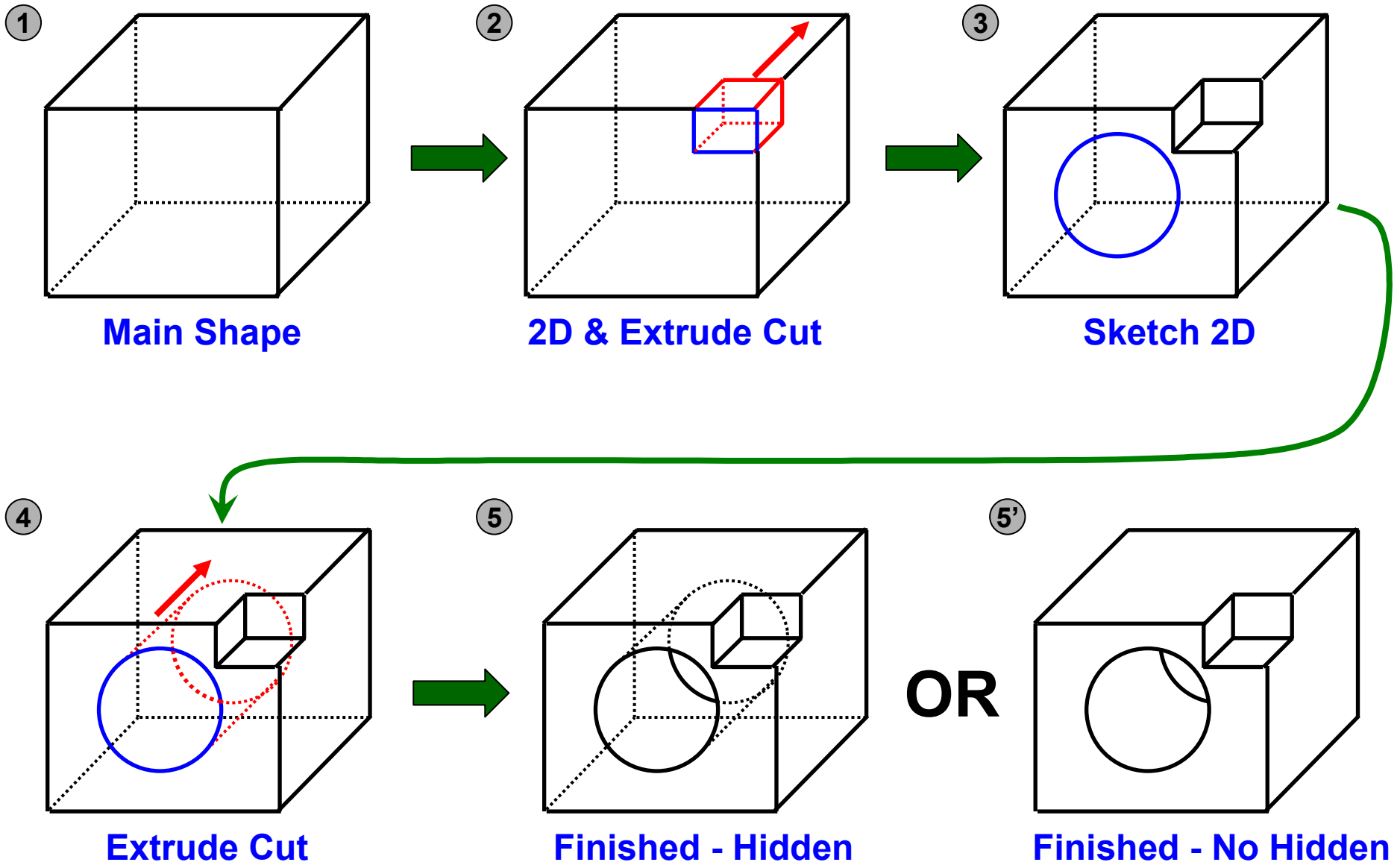
Extrude Boss



Revolve

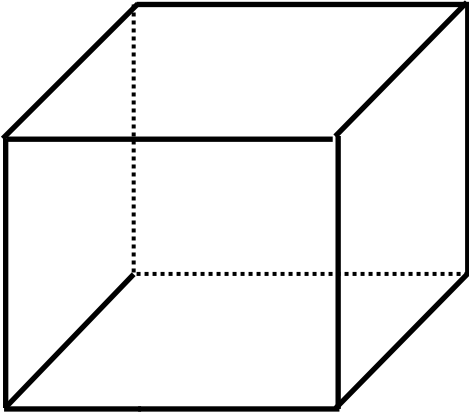


Sketching basics - Boolean operations: Cuts



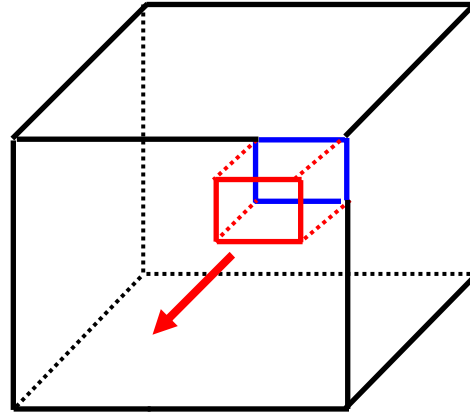
Sketching basics - Boolean operations: Extrusion

1



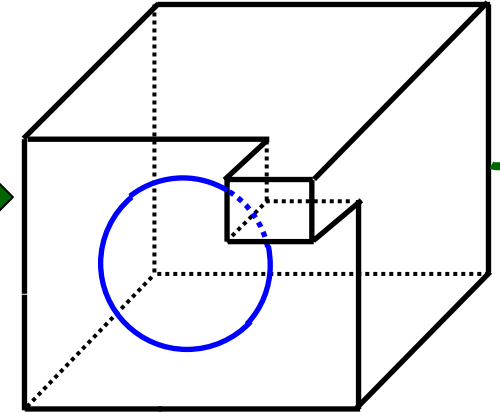
Main Shape

2



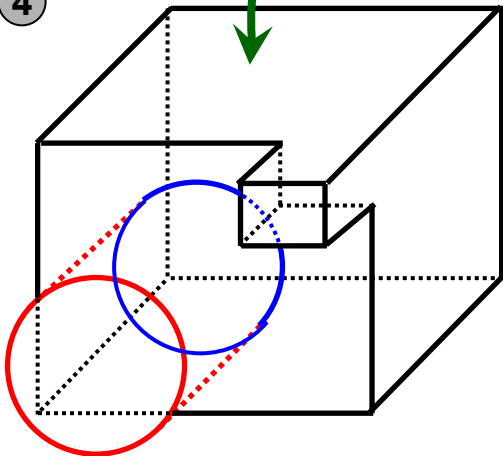
Sketch 2D & Extrude Boss

3



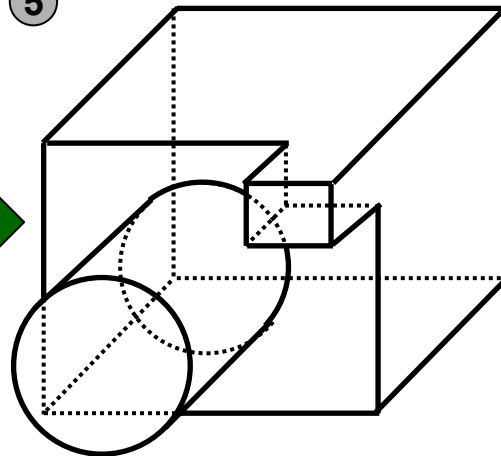
Sketch 2D

4



Extrude Boss

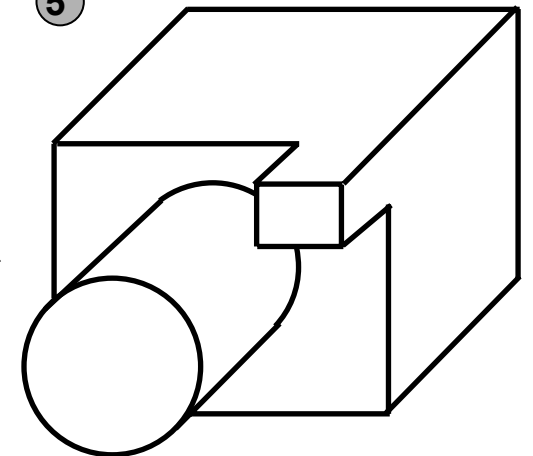
5



Finished - Hidden

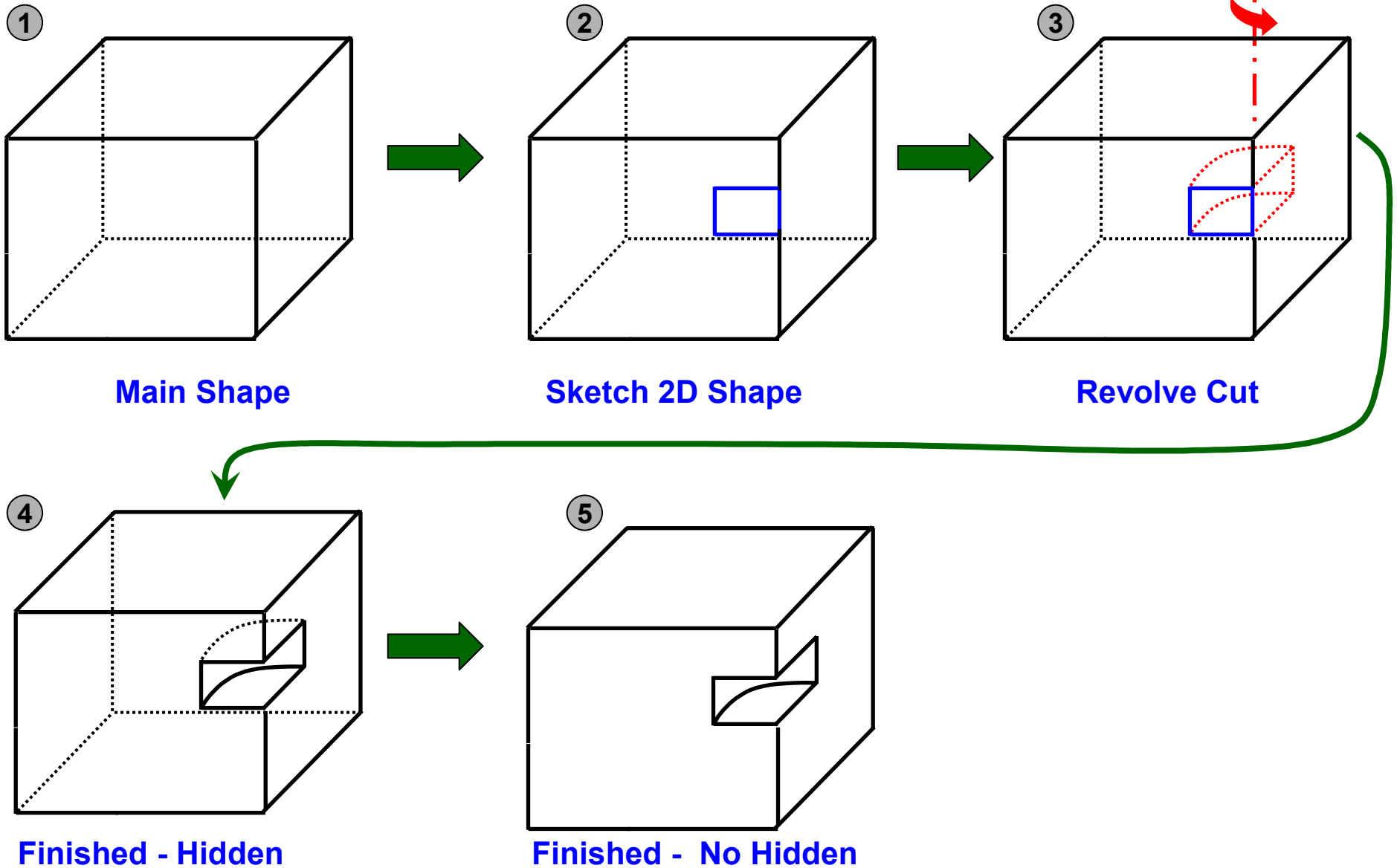
OR

5'



Finished - No Hidden

Sketching basics - Boolean operations: Revolution



Sketching rules of thumb

Real life rules / grading rule:

- ⊙ Is it important?
- ⊙ Can it be sketched with a reasonable amount of effort?
- ⊙ If yes to both, it should be there!

Other helpful hints:

- ⊙ Use hidden lines (light dotted lines) to show hidden features
- ⊙ **Guidelines**
 - ✓ Evidence of light guidelines will be **required** for full credit
 - ✓ Modify the guidelines until it looks right
- ⊙ Using arrows or text to indicate motion and/or direction of motion

Types of 3D sketching - Isometric

Characteristics:

- ⊙ Front is NOT parallel to picture plane
- ⊙ Sides are 30° from horizontal
- ⊙ Distances parallel to sides or vertical lines are actual distance
- ⊙ Distances drawn / measured along other angles are not actual distance

Advantages

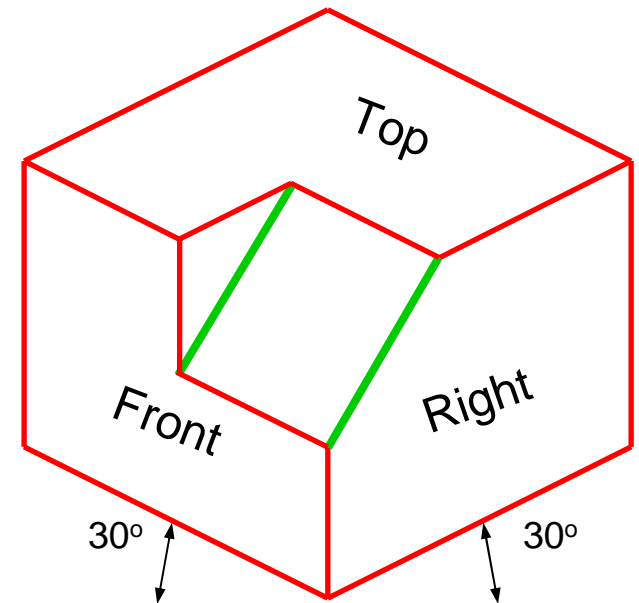
- ⊙ Side figures are less distorted than oblique
- ⊙ Looks closer to real life
- ⊙ Shows the sides generally used in blueprints (orthographic views)

Disadvantage

- ⊙ Can be difficult to draw

How:

- ⊙ Draw a box which encompasses your part
- ⊙ Draw light horizontal guide line
- ⊙ Draw vertical line for front edge of isometric box
- ⊙ Draw guide lines for extrudors
- ⊙ Draw light isometric box as a guide
- ⊙ Draw 2D sketches same as for oblique side features
- ⊙ Extrude/revolve/cut



Types of sketching – 2D Orthographic

Characteristics:

- ⊙ Front view is parallel to picture plane

Advantage

- ⊙ Easy to show true dimensions
- ⊙ Features on front face are true shape & size
- ⊙ Possible to convey great deal of information

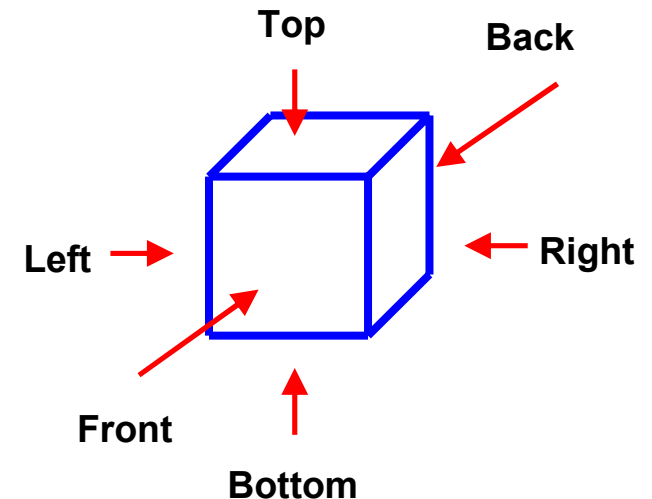
Disadvantage

- ⊙ “Reader” must use imagination to visualize 3D

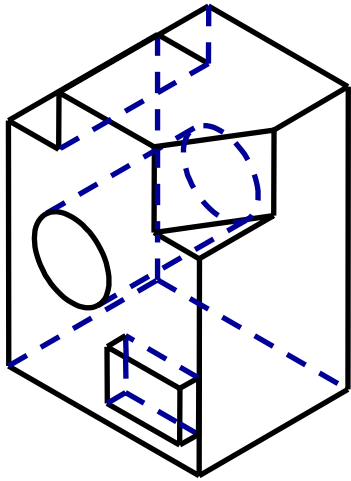
How:

- ⊙ Draw consistent boxes that lay out desired views
- ⊙ Orient so complicated shapes are on the front face
- ⊙ Start with front view, develop other sketches
- ⊙ Check to make sure all features are accounted for

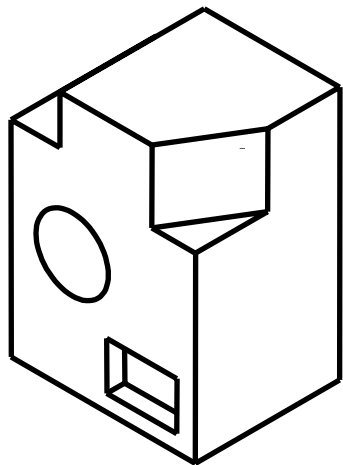
Use direction that best communicates ideas



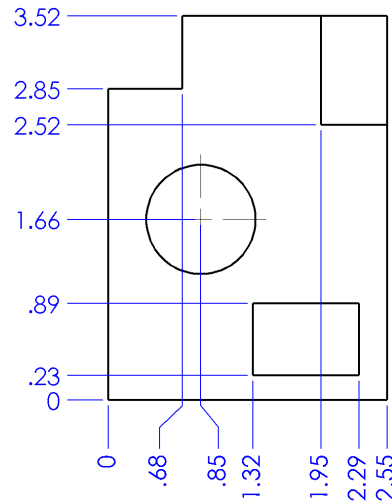
Types of sketching – Isometric vs orthographic



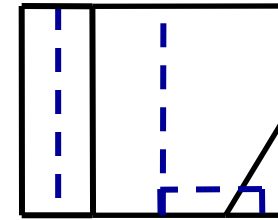
Isometric
(hidden lines)



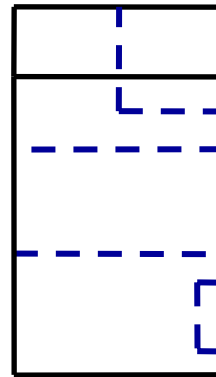
Isometric
(no hidden lines)



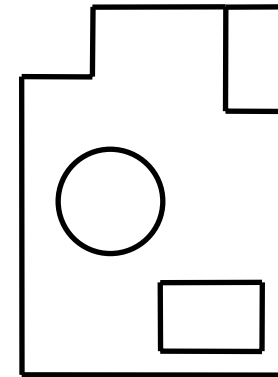
Orthographic
(Front view
with dimensions)



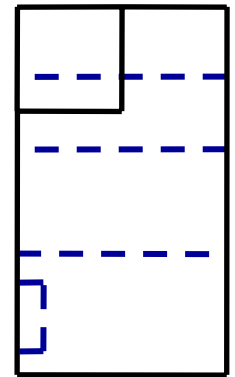
Top



Left



Front



Right

Orthographic

It is most common to use:

- Front
- Right
- Top

Types of sketching – 3D Oblique

Characteristics:

- ⊙ Front view is parallel to picture plane & contains 2 perpendicular axes
- ⊙ Extrudors usually 45° from horizontal
- ⊙ Extrudors generally same scale as front face edges (we will use this method)

Advantage

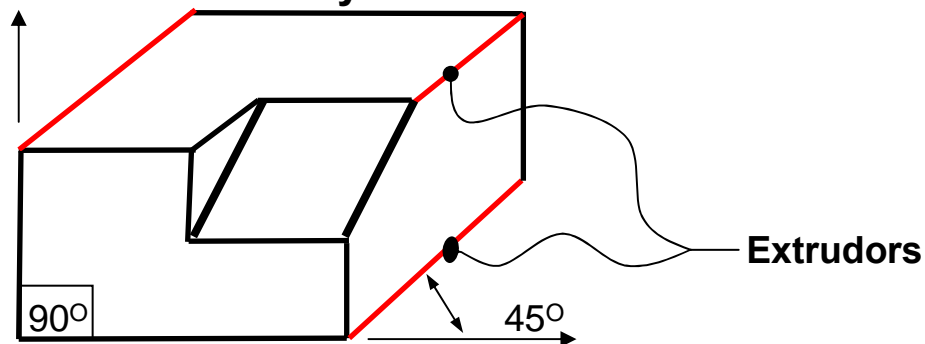
- ⊙ Easy
- ⊙ Features on front face are true shape & size

Disadvantage

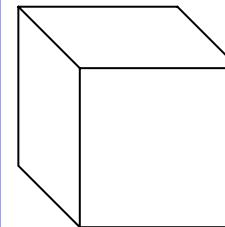
- ⊙ Side features can appear distorted

How:

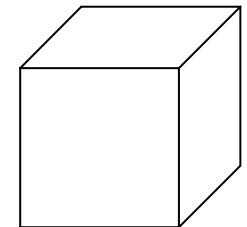
- ⊙ Draw a box which encompasses your piece
- ⊙ Orient so complicated shapes are on the front face
- ⊙ Start with your 2D sketch and extrude/cut/revolve



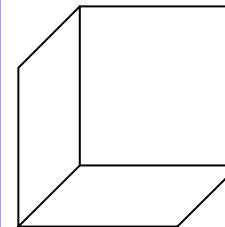
Use direction that allows best communication



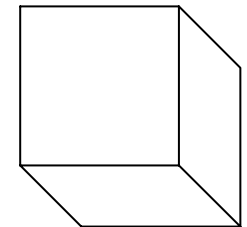
Left & Top



Right & Top



Left & Bottom

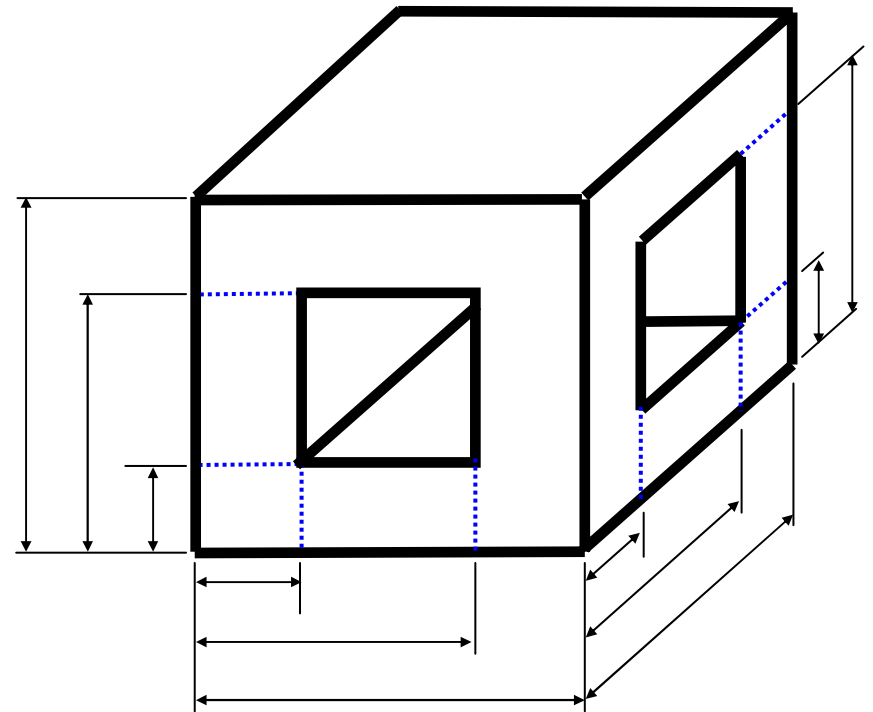
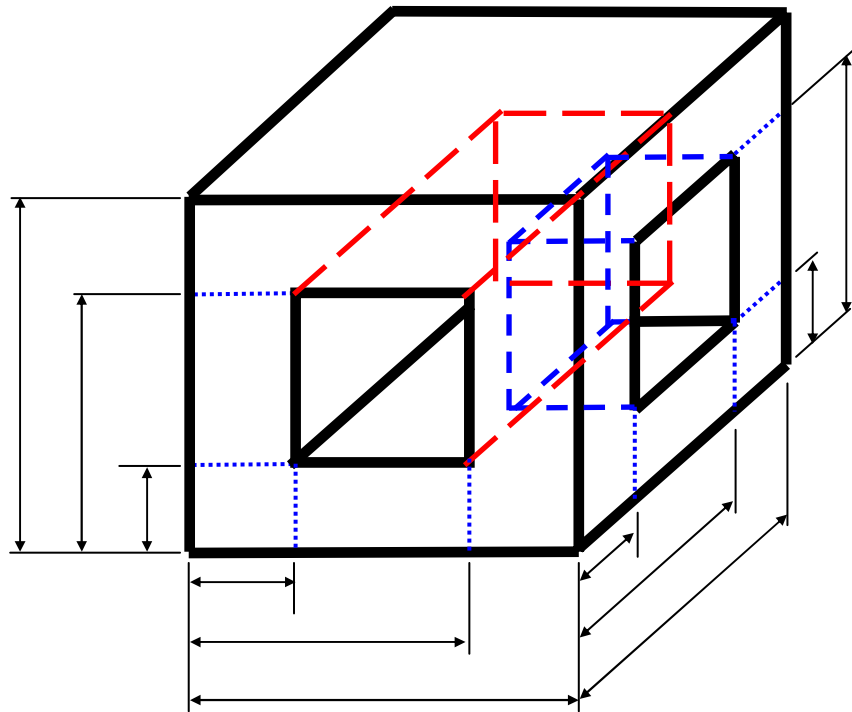


Right & Bottom

Types of sketching - Oblique Cont.

Hints for making features on side faces:

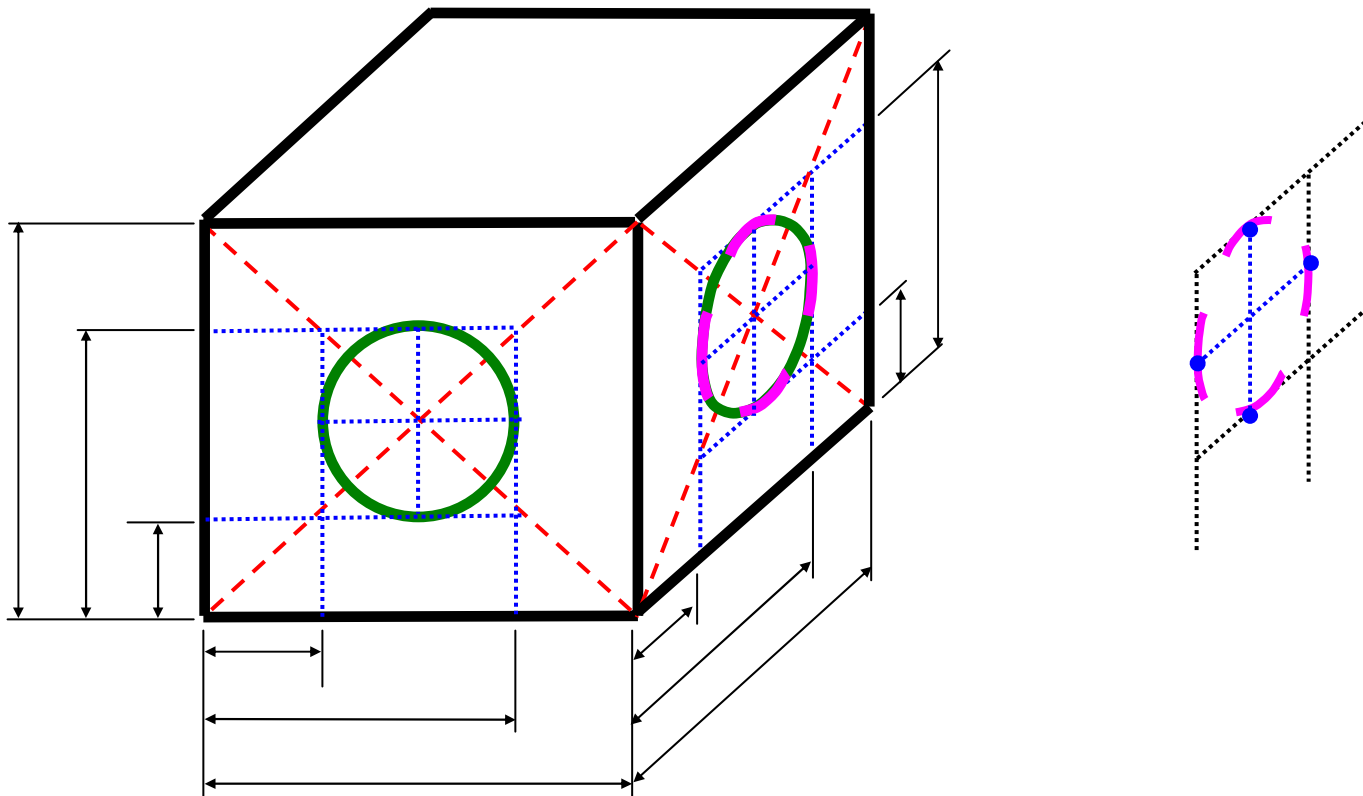
- ⦿ “Measure off” on the extrudors to obtain outer edges of features on side face
- ⦿ Sketch in square or triangle



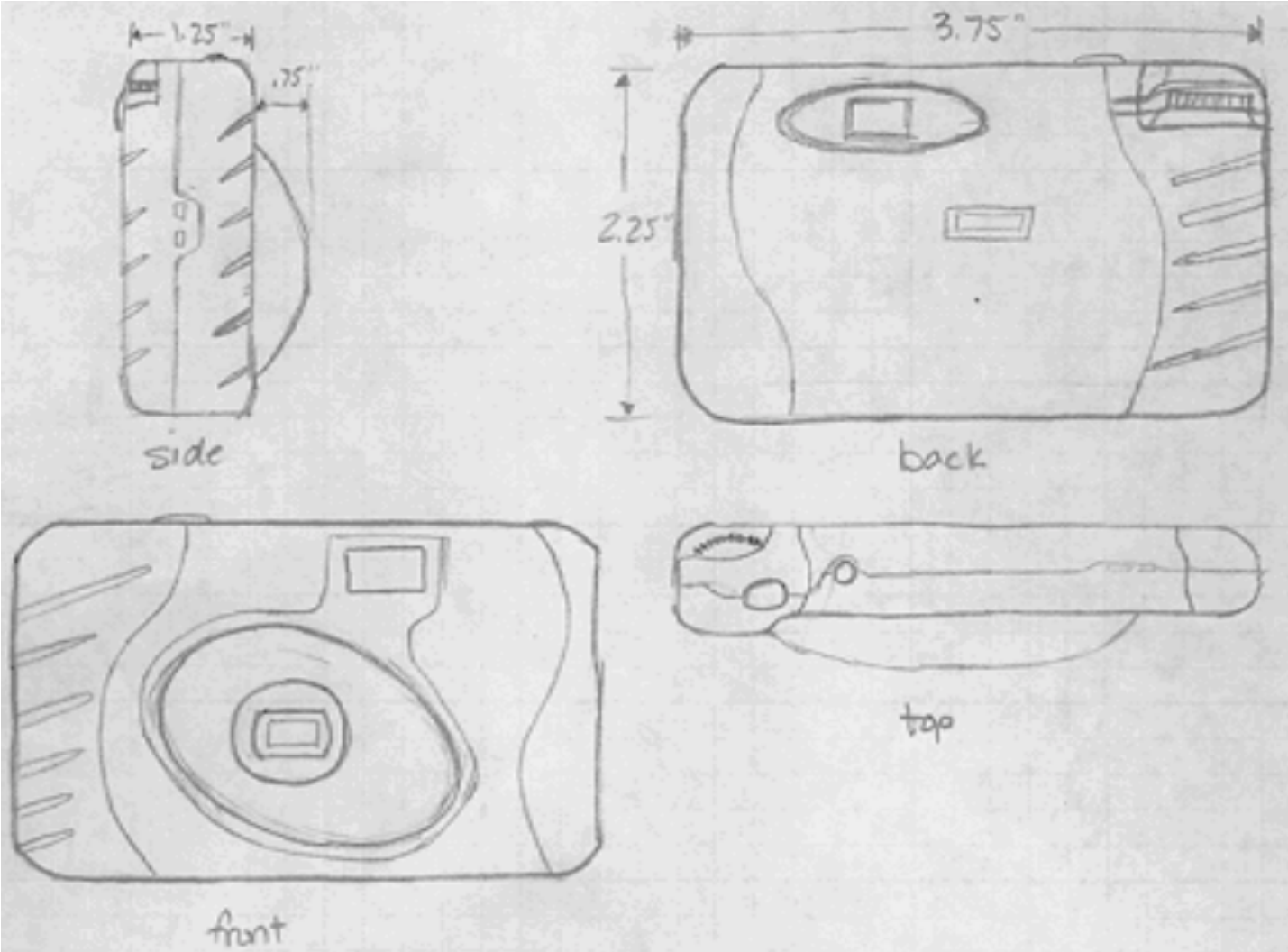
Types of sketching - Oblique Cont.

Circles on side faces:

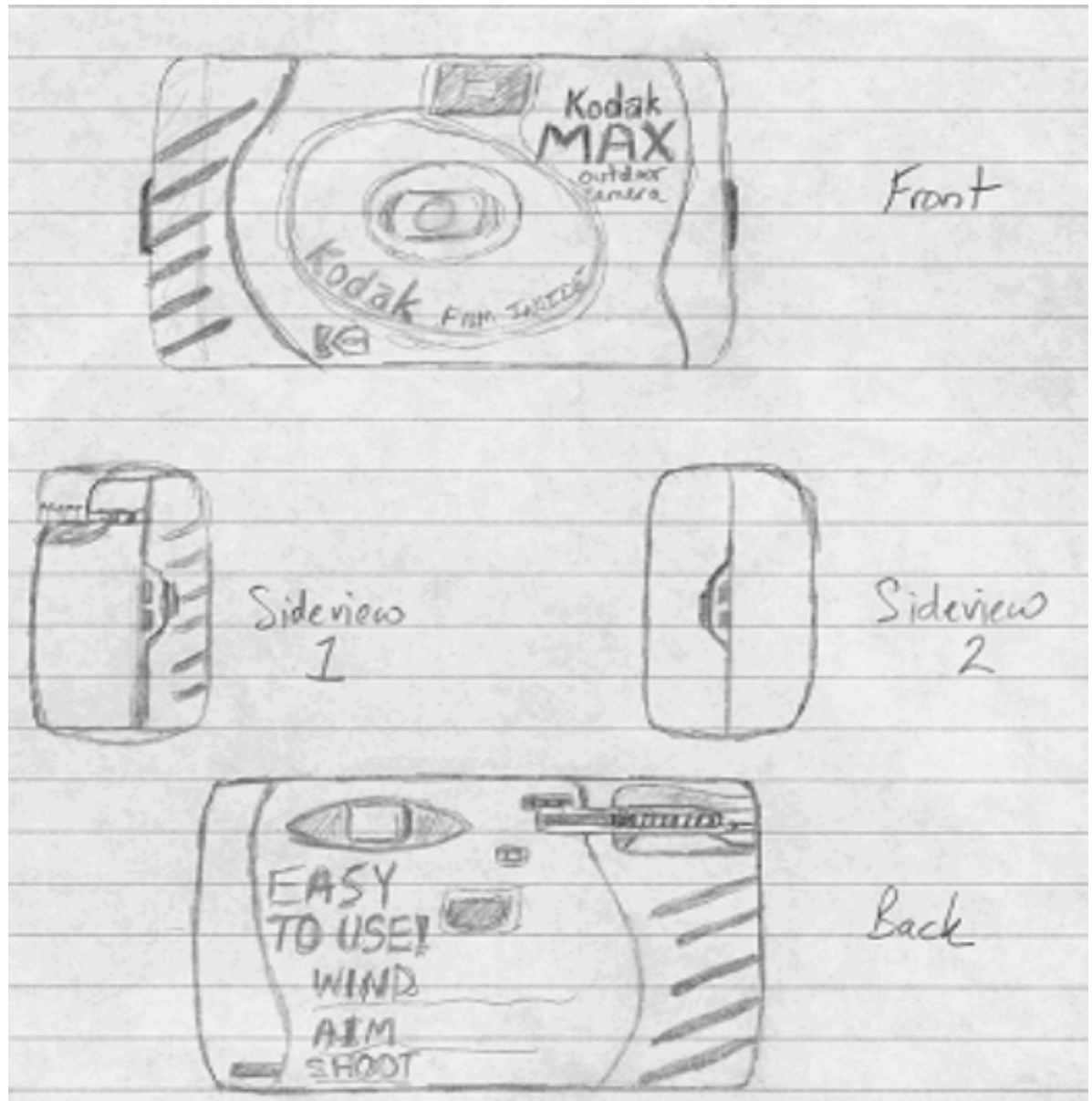
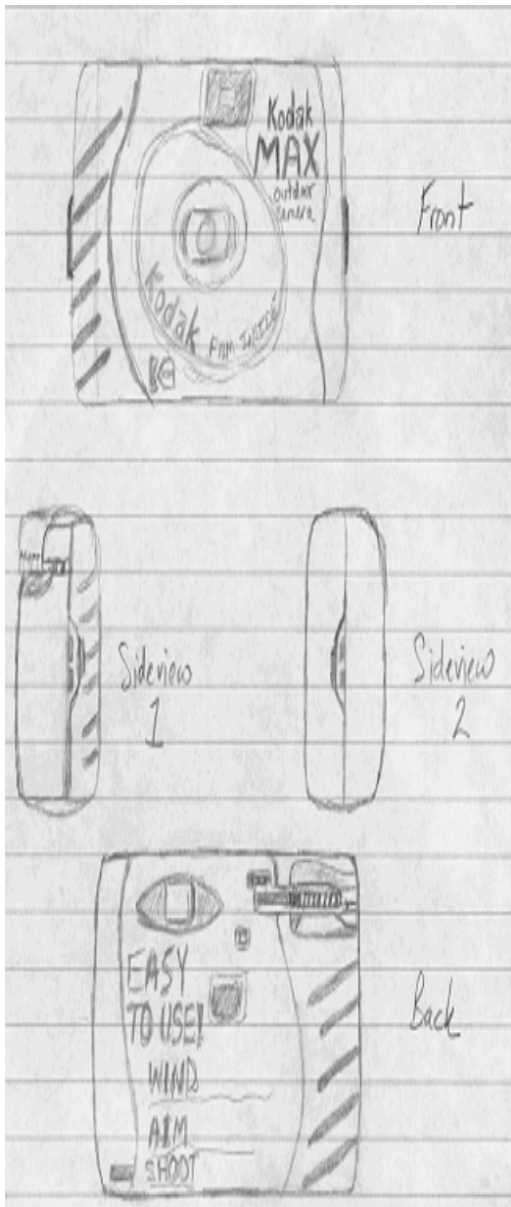
- ⊙ Use diagonals to locate centers
- ⊙ Measure off projectors to obtain box around circle
- ⊙ Draw segments of the ellipse at tangent points (center of box edges)
- ⊙ Notice that the circle on the right face appears elliptical



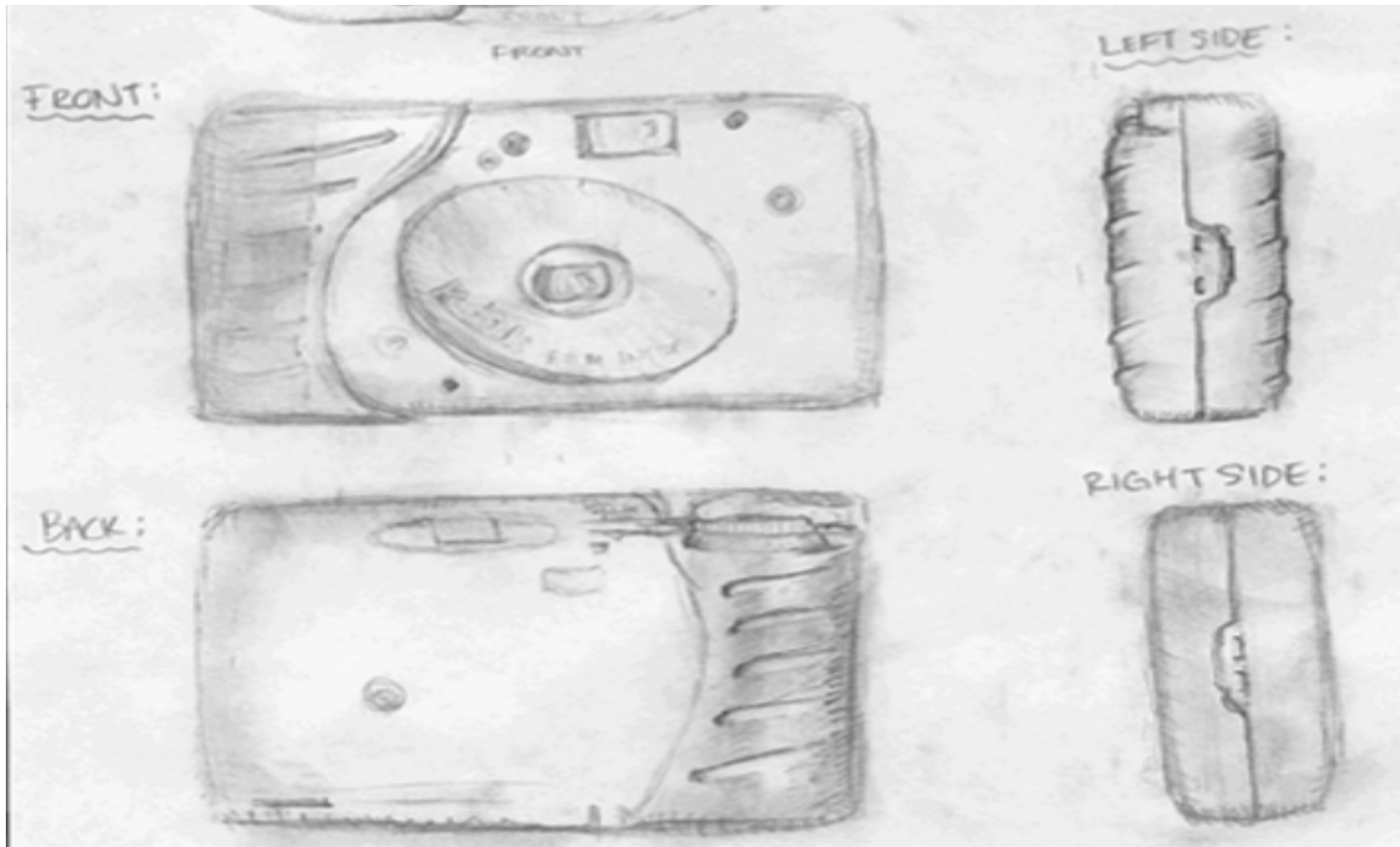
Example - Size



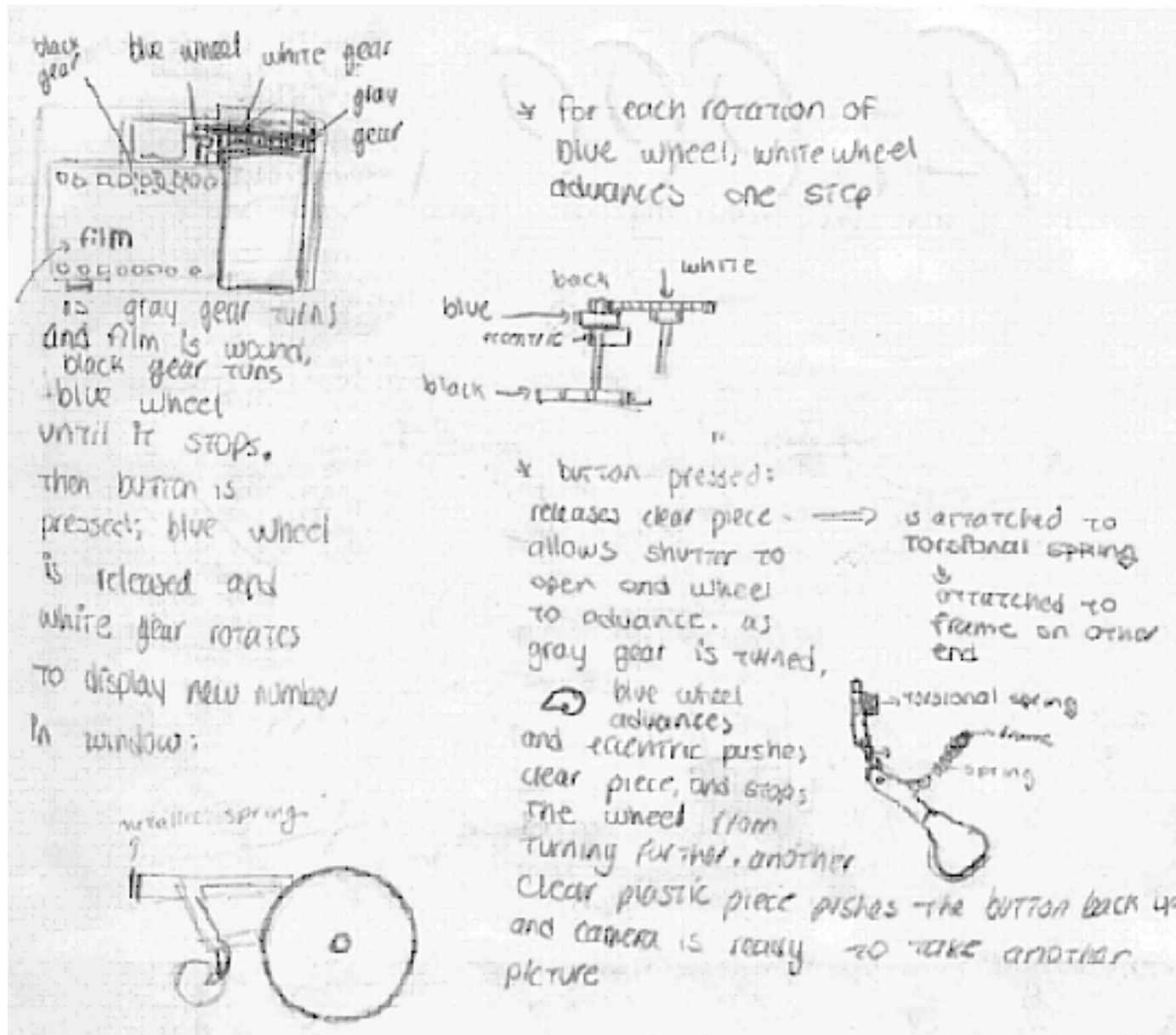
Example - Proportion



Example - Likeness



Example – Explanation and notes



PROJECT MANAGEMENT BASICS

Why project management?

PURPOSE

- ⊙ Skills/knowledge needed to effectively manage a group project

IMPORTANCE

- ⊙ Scheduling and understanding/handling risk is crucial to success

2.000 GOALS

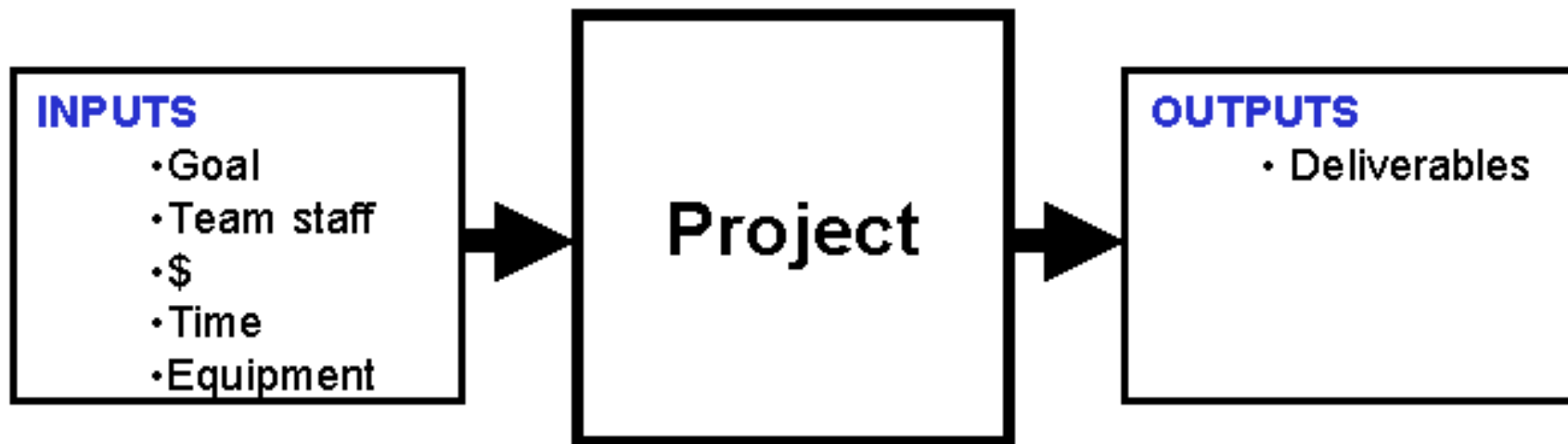
- ⊙ Break complex project into manageable tasks
- ⊙ Assign responsibilities
- ⊙ Set reasonable milestones
- ⊙ Perform risk analysis
- ⊙ Develop project plan

Where you will use this

- ⊙ Projects
- ⊙ Lab
- ⊙ In-class exercises

Project management

The art of getting things done.....



Common stages of projects

Stage 1: Defining the goals of the project:

- ⊙ Most important stage

Stage 2: Define project tasks/activities:

- ⊙ Clear statements of work

Stage 3: Determine and verify resource requirements:

- ⊙ People Time Money Space Computers/software Others.....

Stage 4: Identify risks and develop mitigation (backup) plans:

- ⊙ People Time Money Space Computers/software Others.....

Stage 5: Develop a schedule

- ⊙ Gantt chart

Stage 6: Execute the schedule

- ⊙ Just do it!

Stage 7: Finish the project and assessing performance

Project resources

We have provided an Excel spreadsheet to help you do resource analysis

See tutorial section of website to download

This is sheet one of the spreadsheet

Project Development Template

Project: Project Title

Revision: #

#	Goal	Success	GANTT task	Resources	Risk(s)	Mitigation	Owner(s)
	Prototype	Prototype ready to test	Make prototype	Machine shop, material, John	Only John knows how to make.	Someone else should learn to machine.	John and Casey

Schedule – Gantt chart

This is sheet two of the spreadsheet

Project Title
#

INSTRUCTIONS:
 - Change cells with backgrounds and blue text
 - All other cells are locked and can not be changed

Start	Days	Finish	Owner(s)	M	T	W	R	F	Sa	Su	M	T	W	R	F	Sa	Su	M	T	W	
				25-Jun	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun	01-Jul	02-Jul	03-Jul	04-Jul	05-Jul	06-Jul	07-Jul	08-Jul	09-Jul	10-Jul	11-Jul	
25-Jun	5	29-Jun	Group																		
2-Jul	2	3-Jul	Group																		
09-Jul	1	9-Jul	Group																		
16-Jul	22	6-Aug	Group																		
28-Jul	7	3-Aug	Group																		
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