Aalto University
School of Engineering

Functionality

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Pedagogy

Lecture: product functions and design simplification.

Team task: Identify the functions in product.

- Subtract and operate method by subassembly
- Necessary and secondary functions

Personal Homework: Come up with 3 ideas to simply the design functionally

Outline

Overall Function

Function Tree

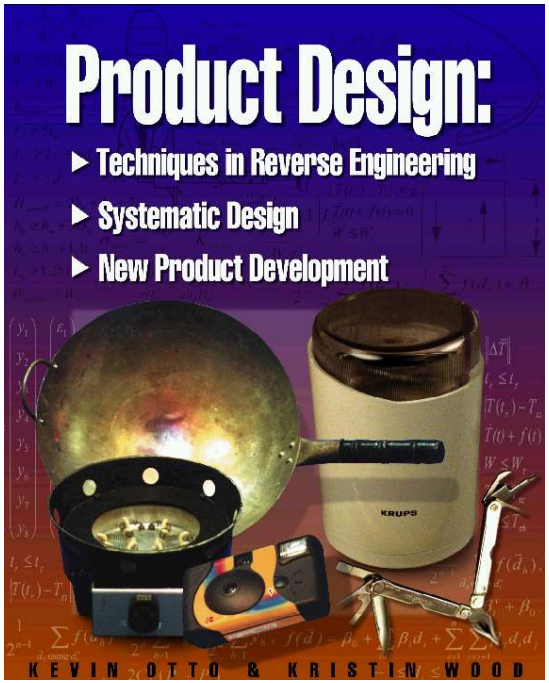
Ideality

Itself Problem

Free Resources

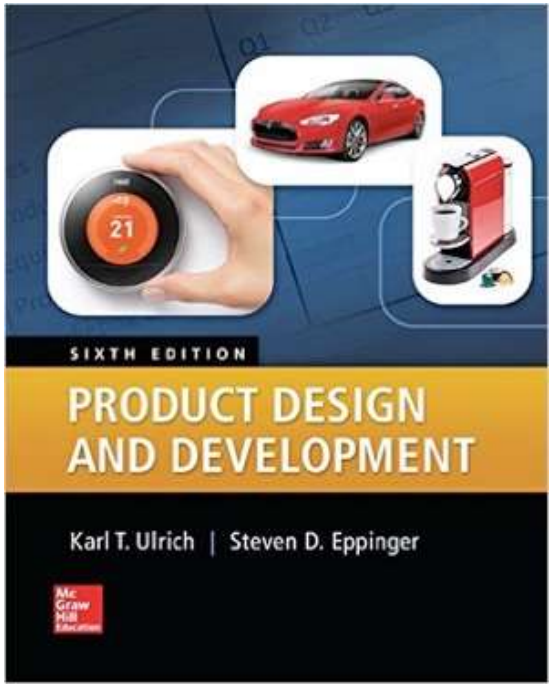
Primary and Secondary functions

Reading



Chapter 5

Chapter 6



Chapter 7

Function

What is a function?

Function

A *function* is a behaviour with intent.

- Your device does something that you want.
- Your device does something that satisfies the customer needs.

What is the function?

Open Cans

What is the function?

Open Cans

What is the function?

Clip
Nails

What is the function?

Clip
Nails

What is the function?

Toast
Bread

Product Function

A *function* is a simple expression of intended behavior

It has a subject (a noun)

It has a predicate (a verb)

It might have an adverb.

It is not a sentence.

Toast Bread

Toast Bread
Evenly

What is the function?

The Overall Function

Many systems do several functions

The *overall function* is the main function of the system

What is the function?

Transport
Persons

What is the function?

What is the function?

Allow Vehicle Access

The subtract and operate procedure

To determine the overall function of a sub-system:

1. Subtract the sub-system from the system.

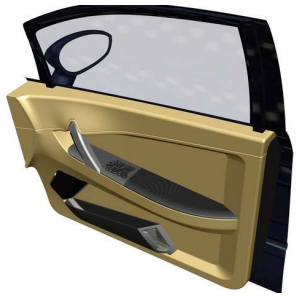
2. Operate the system.

3. What fails?

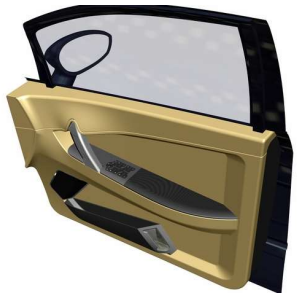
The inverse of that failure is the sub-system function.

Lefever, D. and K. Wood, “Design For Assembly Techniques In Reverse Engineering And Redesign,” *ASME Design Theory and Methodology Conference*, 1996.

What is the function?

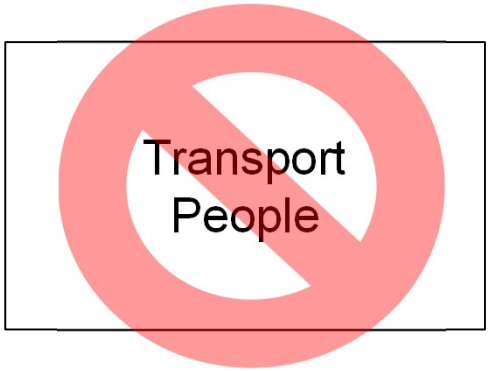


What is the function?



Protect Occupants

What's the function?



What is the function?

Outline

Overall Function

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Ideality

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Free Resources

Primary and Secondary functions

Functions and Subfunctions

Any function can always be split into subfunctions

Completing the subfunctions completes the function

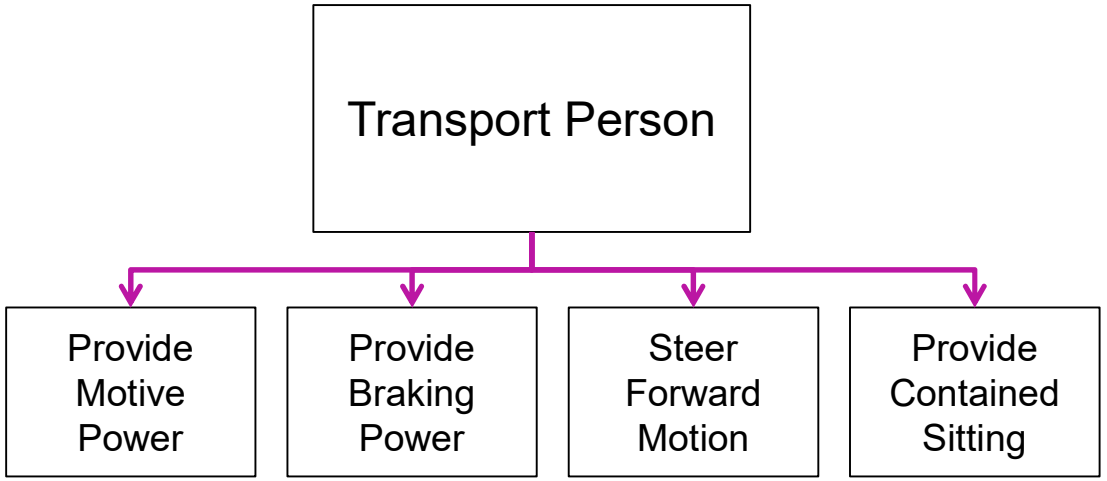
Transport Person

What subfunctions must the device do?

Functions and Subfunctions

Any function can always be split into subfunctions

Completing the subfunctions completes the function

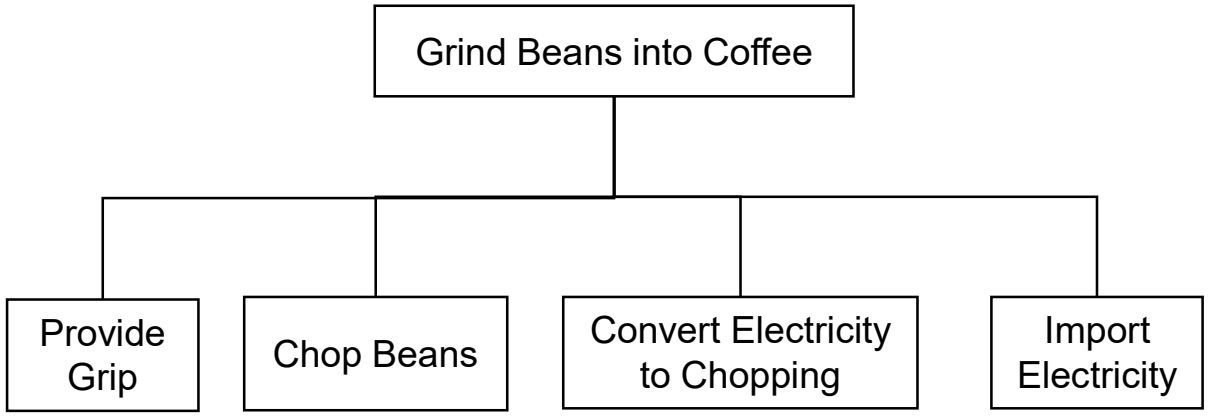


Subfunctions

What is the overall function?

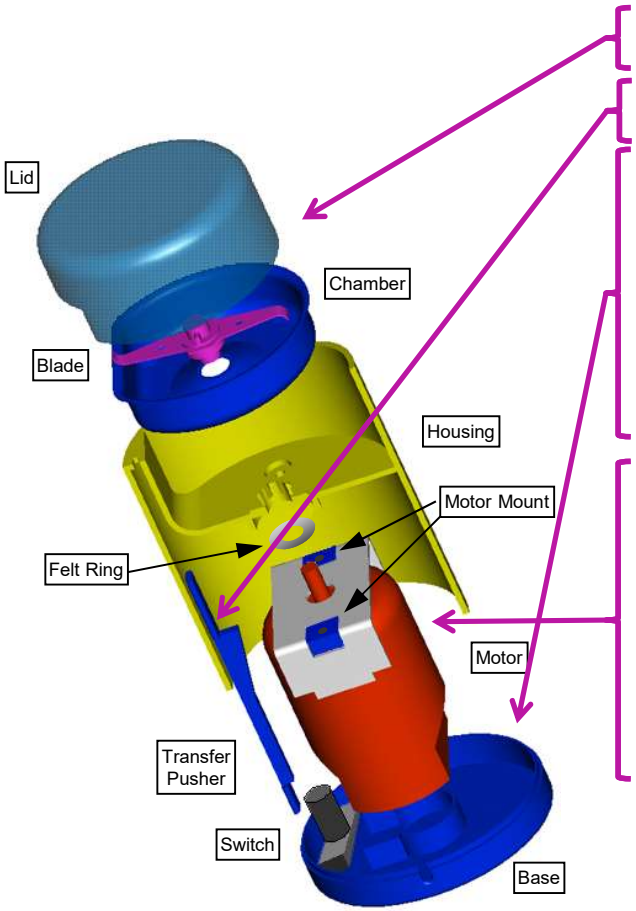
What are the subfunctions?

Subfunctions



The Parts

What functions does each part do?



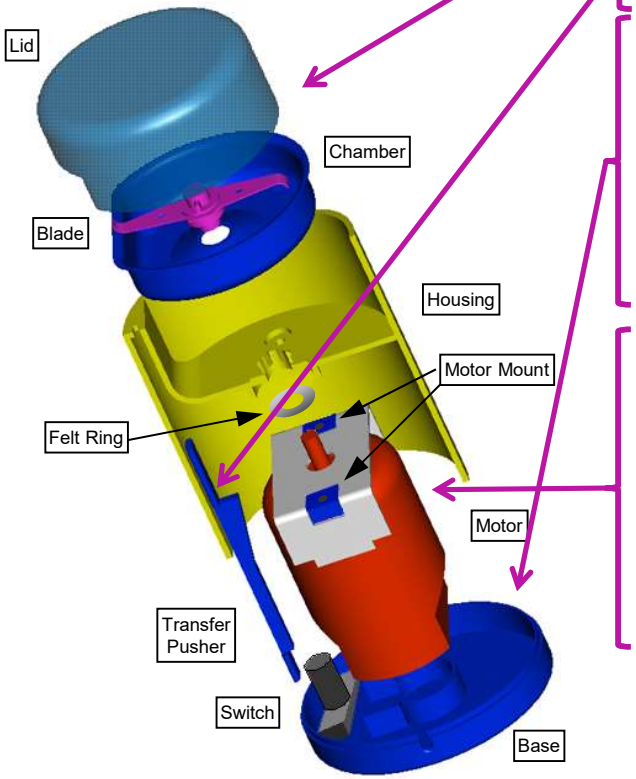
Part IDc				Name	Q
			001	Lid	1
A1				GRINDER ASSY	1
			002	Transfer Pusher	1
	S1			BASE ASSY	1
			003	Power Switch	1
			004	Power Cord	1
			005	Base	1
		S11		WIRING ASSY	1
			006	Wire	1
			007	Fuse	1
			008	Connector	1
			009	Clamp	1
			010	Casing	1
	S2			BODY ASSY	1
			011	Blade	1
		S21		MECH ASSY	1
			012	Chamber	1
		S212		MOTOR & BODY	1
			013	Felt Ring	1
			014	Screws, self-tapping	2
			015	Body	1
		S2121		MOTOR ASSY	1
			016	Motor Mounts	2
			017	Motor	1

The Subassemblies

The Level 1 subassemblies are

- Lid
- Base Assy
- Body Assy

What is function of each subassembly?



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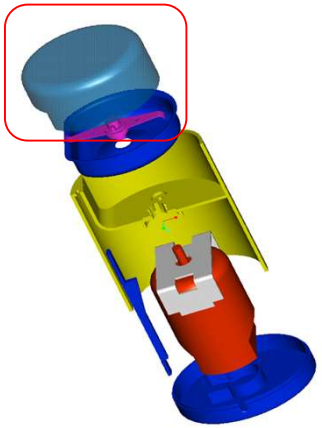
The Subassemblies

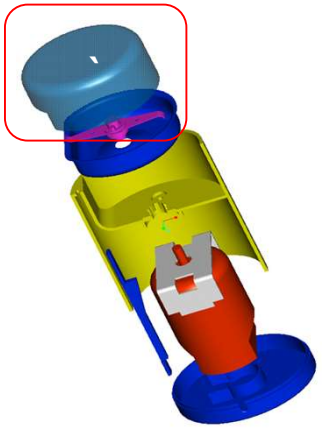
Lid function



What happens if there is no lid?

The Subassemblies

Lid function



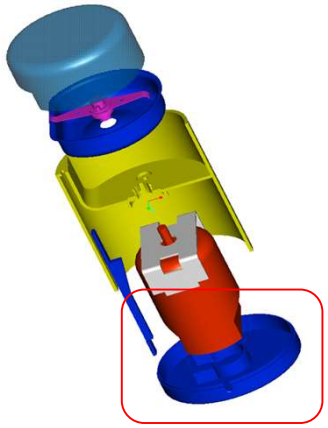
Contain
Chopping

Interface
Power
Actuation

The Subassemblies

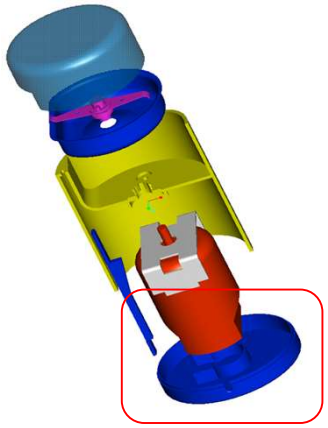
Base Assy function

What happens if there is no base assembly?



The Subassemblies

Base Assy function



Contain Motor Power

Actuate Power

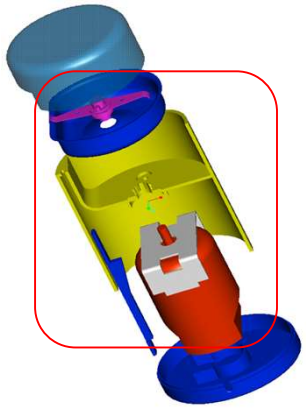
Connect Power

Support Chopping

The Subassemblies

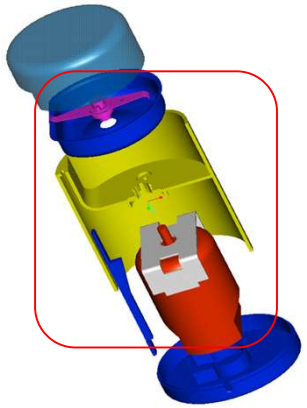
Body Assy function

What happens if there is no body assembly?



The Subassemblies

Body Assy function



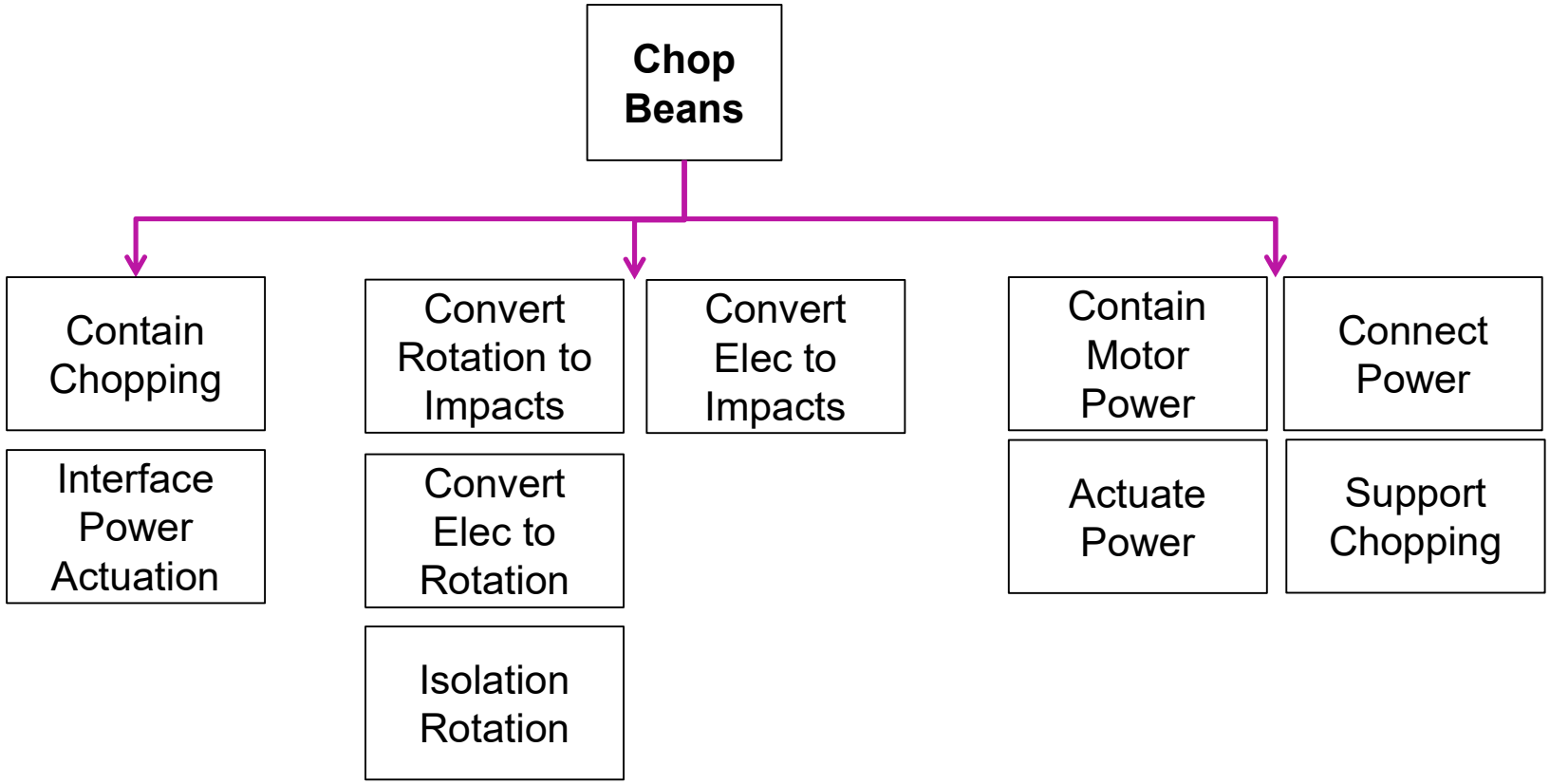
Convert Rotation to Impacts

Convert Elec to Impacts

Convert Elec to Rotation

Isolation Rotation

Subassembly based function tree



Outline

Overall Function

Function Tree

Ideality

Itself Problem

Free Resources

Primary and Secondary functions

Elegant Design

Elegant Design

A simpler design is better.

Henry Maudslay
“Put to yourself the question:
What business has it to be there?”

Kelly Johnson
“Keep it simple, stupid.”

Why think functionally?

How do you use functions to generate better concepts?

Hold a brainstorm session for other concepts to do the function

Open Cans

Why think functionally?

How do you use functions to generate better concepts?

Brainstorm other ideas for fullfilling the function

Despite their popularity, group brainstorming sessions have been shown to be one of the worst methods to generate concepts. *Any* other method is better.

Why think functionally?

How do you use functions to generate better concepts?

We'll discuss three methods

- The Itself Problem
- Freely Available Resources
- Primary and Secondary Functions

The Ideal Final Result (IFR)

The *Ideal Final Result* is what the customer really wanted.

- Based on the Customer Needs, and
- Independent of the equipment, process or solution currently used.

What is the desired customer result?

Use complete "out of box" thinking

- Helps the team reach breakthrough solutions
- Window to future technology directions

Example

What is the IFR for a microwave oven?

Overall

Function = Cook Food

Cook
Food

Example

What is the IFR for a microwave oven?

IFR = Cook Food

with

No electricity

Instantly cooked

No handling effort

No radiation

No countertop space

No …

Open it and it's cooked

Example

What is the IFR for a microwave oven?

IFR = Cook Food

with

No electricity

Instantly cooked

No handling effort

No radiation

No countertop space

No …

Open it and it's cooked

Example

Illuminate Space

Example

Automatically illuminated without lightbulbs

Example: Car

Transport
Person

Example: Car

Instantly transported. No big car.

Example: Car

Backing off full ideal…

No big car. Gets further into the last mile.

Example

Allow Entry

Example

No parts, prevents entry.

Example

Backing off full ideal…

Less parts. More entry/exit space.

Formulating the IFR

Write the function statement

Write the IFR taking into consideration that this result must:

- *Preserve the original function.*
- *Eliminates the system deficiencies.*
- *Does not make the system more complicated. (Uses free or available resources)*
- *Does not introduce new disadvantages.*

Law of Ideality

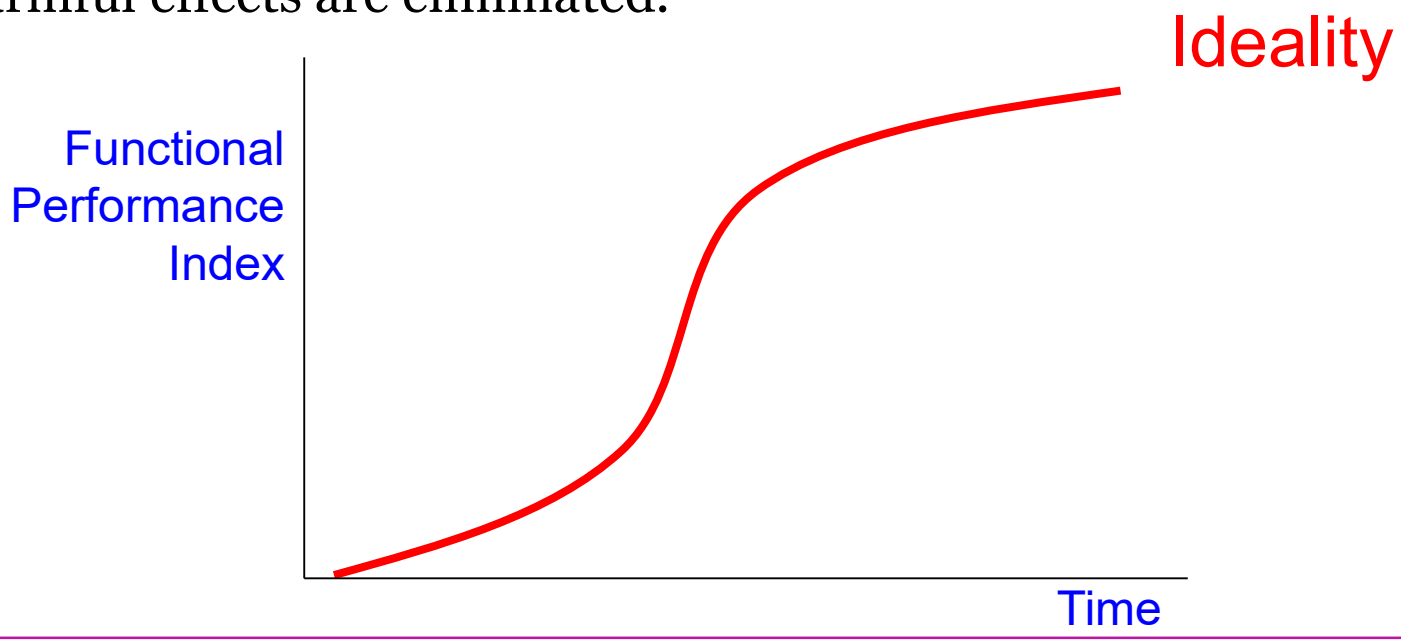
Any Technical System Through It's Lifetime:

- Becomes more simple
- Becomes more reliable
- Becomes more effective
- Becomes more ideal
- It costs less
- It requires less space
- It wastes less energy
- Ideality Always Reflects Maximum Use of Resources
- At Ideality, the Mechanism Disappears while the Function Remains

The Ideal Final Result (IFR)

The Ideal Final Result is the extreme result of Ideality

- All benefits are delivered fully.
- Costs are reduce to zero.
- Harmful effects are eliminated.



The Ideal Final Result (IFR)

The Ideal Final Result is the extreme result of Ideality

- All benefits are delivered fully.
- Costs are reduce to zero.
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= Maximize All Useful Functions
Eliminate All Harmful Functions

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The Ideal Final Result (IFR)

Getting to the Ideal Final Result needs consideration of

1. **Tools**
2. **Function**
3. **Objects**

Tools and Objects

Consider your product simply as a *tool* to do the *function*.
A mechanism or means to do something.
Consider it working an *object*.

Find ways for the *object* to do the *function* without the *tool*.

Tools and Objects

Consider your product simply as a tool to do _*function*__.

A means to do something.

Consider it working an _*object*_.

Cook Food	Illuminate Space	Transport Person

The “Itself” Problem Statement

Consider your product simply as a tool to do _function__.

A means to do something.

Consider it working an _*object*_.

Can you make the _object_ *itself* do the _function_?

Thereby without the _product_. How? Generate ideas.

Itself Example: Microwave Oven

The *oven* is a tool to *cook*.

The object is *food*.

Can we make *food cook*?

Cook
Food

Itself Example: Microwave Oven

The *oven* is a tool to *cook*.

The object is *food*.

Can we make *food cook*?

Cook
Food

Itself Example: Light Bulb

The *light bulb* is a tool to *illuminate*.

The object is *space*.

Can we make *space illuminate*?

Illuminate space

Itself Example: Light Bulb

The *light bulb* is a tool to *illuminate*.

The object is *space*.

Can we make *space illuminate*?

Illuminate space

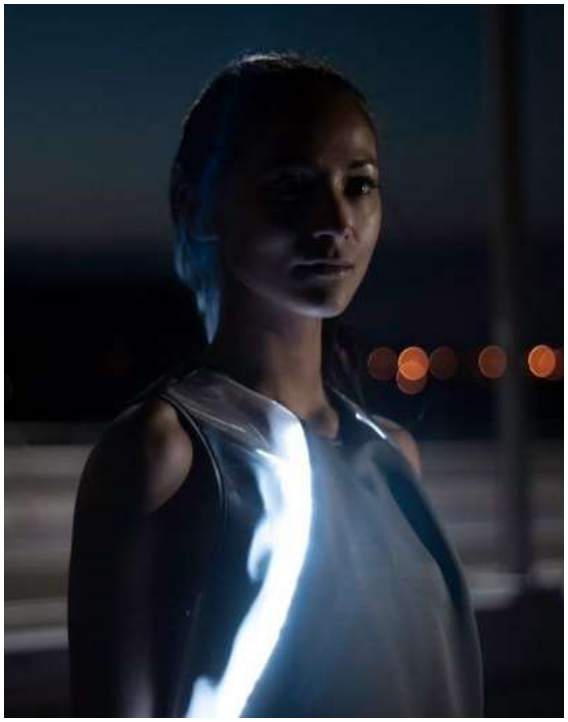
Itself Example: Light Bulb

The *light bulb* is a tool to *illuminate*.

The object is *tasks*.

Can we make *tasks illuminate*?

Illuminate tasks



Itself Example: Car

The *car* is a tool to *transport*.

The object is *persons*.

Can we make *persons* *transport*?

Transport
Persons

Itself Example: Car

The *car* is a tool to *transport*.

The object is *persons*.

Can we make *persons* *transport*?

Transport
Persons

Itself Example: Car

The *car* is a tool to *transport*.

The object is *persons*.

Can we make *persons* *transport*?

Transport
Persons

Itself Example: Door

The *door* is a tool to *allow entry*.

The object is *persons*.

Can we make *persons allow entry*?

Allow
Persons
Entry

Itself Example: Door

The *door* is a tool to *allow entry*.

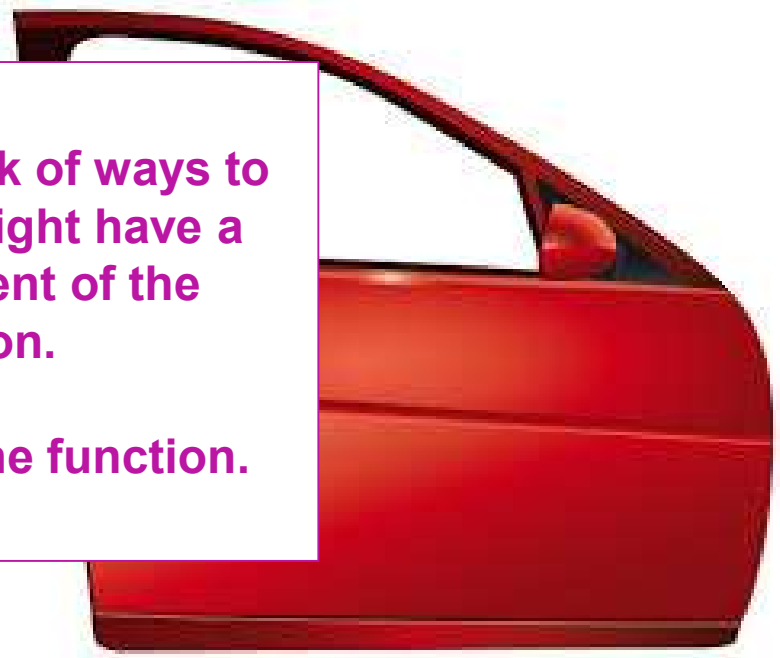
The object is *persons*.

Can we make *person*

If you can't think of ways to do this, you might have a poor statement of the function.

Try restating the function.

Allow
Persons
Entry



Itself Example: Door

The *door* is a tool to *prevent entry*.

The object is *objects (rain, debris)*.

Can we make *rain prevent entry*?

Prevent objects entry

Itself Example: Door

The *door* is a tool to *prevent entry*.

The object is *objects (rain, objects)*.

Can we make *rain prevent entry*?

Prevent objects entry

Outline

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Primary and Secondary functions

Resources

If you cannot make the object do the function itself, perhaps there are other resources which you can use instead.

What is a resource? Anything that is not being used!

Other assets in the customer environment

- Substances
- Fields
- Space
- Time

This is yet another reason to go to the customer's site and see what is there.

Freely Available Resources

Glove Buddie

The Mobile Glove Drying System
Works with standard vents in car
Dries and warms gloves

Uses available air flow through air vent
No electrical hook-up required

Freely Available Resources

Ambi-Pur Car Air Freshener

Fragrance intensity is fully adjustable
Each refill lasts 45 days
1 Perfume Bottle – 8 ml
Fresh floral bouquet

Uses available air flow through air vent
No electrical hook-up required

Freely Available Resources

Spinning wheels before landing

Aircraft tires undergo wear when they impact the runway during landing. Spinning the wheel would reduce wear. A motor could do this but that's added weight and expense.

A freely available resources is the air movement. Small airfoils can be attached to the side of landing wheel, which will spin the wheels on approach.

Freely Available Resources

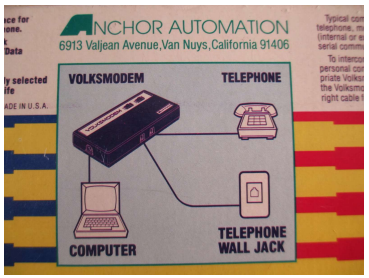
Demise of the modem

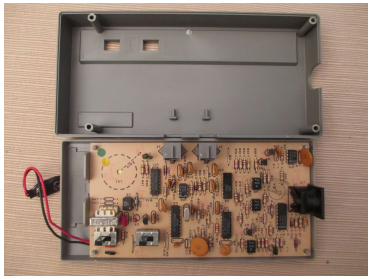
In the 1980s, there was no internet.
Instead, you dialed up servers.
Banks. Bulletin boards. etc.

Used 300 bit/sec serial-port
connected boxes called
modems.

Computer: $2000.
Modem: $300.

How can you provide modem
functionality without a modem?



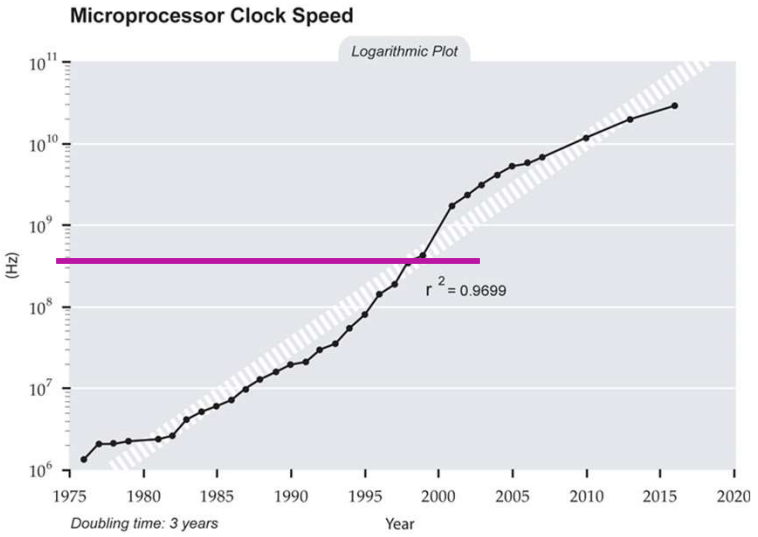


Freely Available Resources

Modems will be 56 kbits/sec, but no faster given telephony technology.

Processor speed is increasing much faster. At what point do we have a free resource?

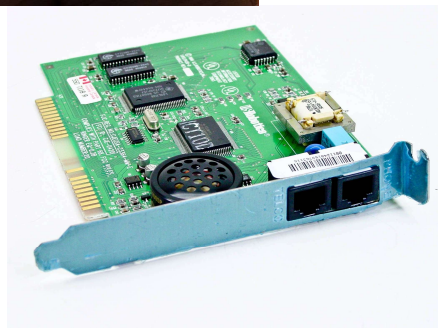
At what point can we use the microprocessor to process all modem commands and yet also do all processing commands?



Freely Available Resources

1997: soft modems

Used microprocessor to do the modem functions. Simple board to do A-to-D & D-to-A.



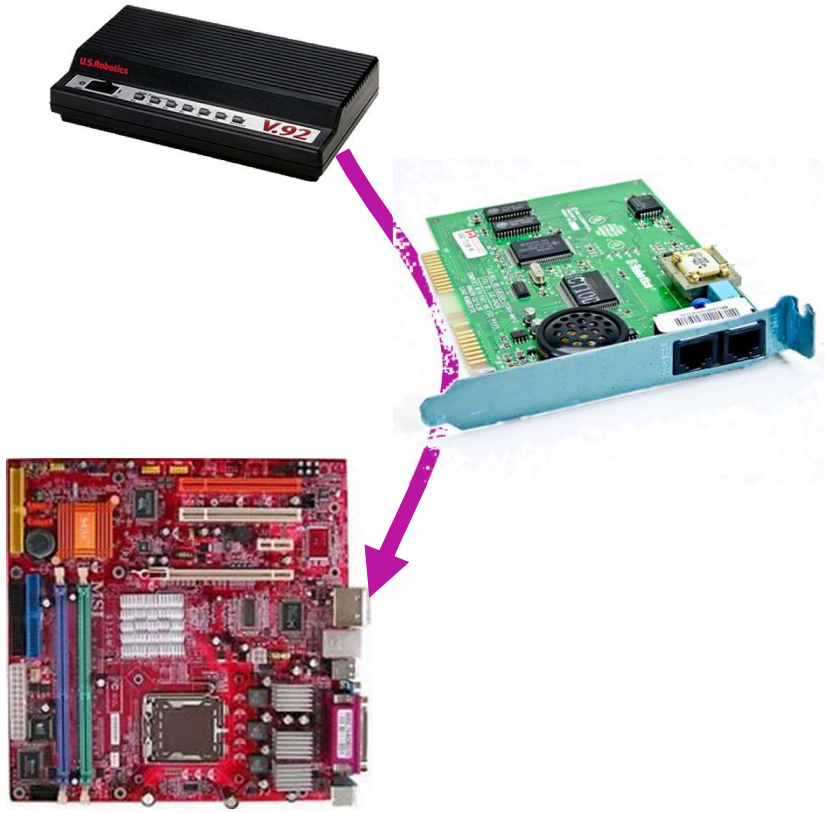
Freely Available Resources

1997: soft modems

Used microprocessor to do the modem functions. Simple board to do A-to-D & D-to-A.

These cards then became integrated onto the motherboard.

Completed the modem functionality without the modem, using new freely available resources.



Freely Available Resources

This approach has been widely repeated.

Initial launch of new functionality on a separate product or PCI card

Card becomes successful

Card functionality then gets integrated into the motherboard

Completed the X's functionality without the X, using the 'freely' available motherboard.

LAN

802.11

Gaming

USB

Surround Sound

“Free Resource” Problem Statement

Reformulate the IFR into a task for a resource.

Can you make the _*resource*_ do the _*function*_ on _*object*_.
How? Generate ideas.

Resources

Consider the customer environment.

Survey for all available resources.

- Energy flows. Material Flows. Information Flows.

Reformulate the IFR into a task for each resource

Finding Available Resources

What are the Substance resources?

What are the Energy resources?

What are the Space resources?

What are the Time resources?

What are the System resources?

What are the Knowledge resources?

- Who knows something that might help solve the problem?

Super-system Elements

***Super-system Elements* are objects that are not system components but interact with the system in a significant way.**

- What are all the other things in the customer environment?
- Can you use any of them?

- It is important to identify the super-system components during the functional analysis.

Many times the super-system components can become resources that can be used to help solve technical problems.

Super-system Elements

Super-system Elements **are objects that are not system components but interact with the system in a significant way.**

- What are all the other things in the customer environment?
- Can you use any of them?

This is another reason why a journey map is useful, showing other systems in the customer environment.

- It is important [illegible] uring the functional ana[illegible].

Many times the super-system components can become resources that can be used to help solve technical problems.

Resource Checklist

Substances

- Waste
- Raw materials
- Modified substances

Time

- Pre / Post work
- Parallel operations

Knowledge

- Information
- Data

Fields

- Energy in system
- Energy in environment

Space resources

- Empty space
- Nesting
- Another dimension

Functions

- Harmful functions
- Primary functions
- Secondary functions

Outline

Overall Function

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Free Resources

Primary and Secondary functions

Harmful Functions

A harmful function produces a flow that is undesired.

A design should ideally *eliminate* a harmful function.

Secondary Functions

Consider your set of subfunctions.

Which directly address a customer need?

Which directly do the overall function?

These are *necessary functions*.

Which functions then prevent a problem generated by a necessary function?

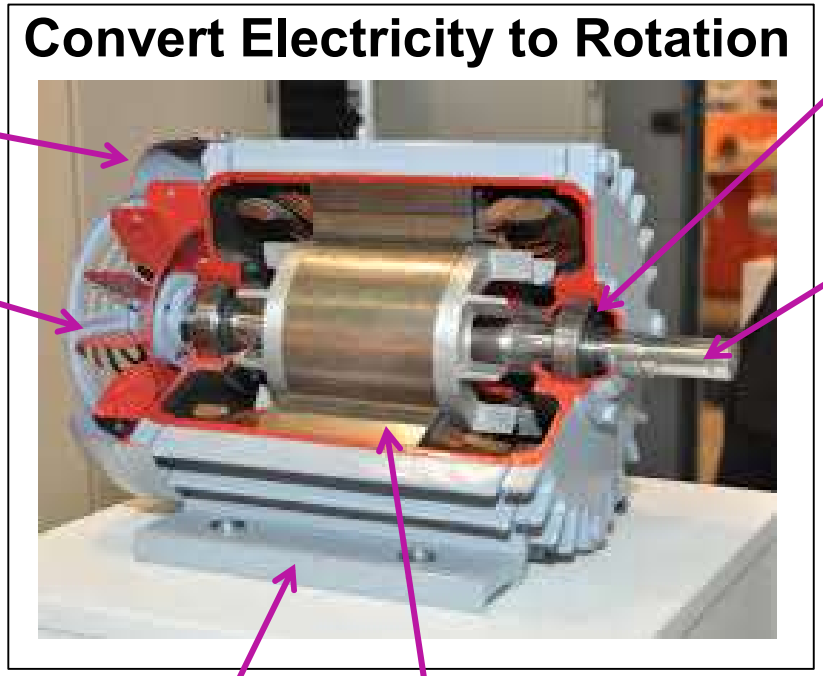
These are *secondary functions*.

Identify this difference by subtract-and-operate.

Does it not work, or does it work poorly / with bad effects?

Primary and secondary functions

Which are necessary?



Trimming

Eliminate secondary functions.

Trimming

Eliminate secondary functions.

Ask:

Can we do the *necessary function* without the *secondary function*?

Trimming

Eliminate secondary functions.

Ask:

Can we do the *necessary function* without the *secondary function*?

Can we make the *necessary function* do the *secondary function*?

Can we use *a free resource* to do the *necessary function*?

Primary and secondary functions

Not all functions exist to generate customer satisfaction.

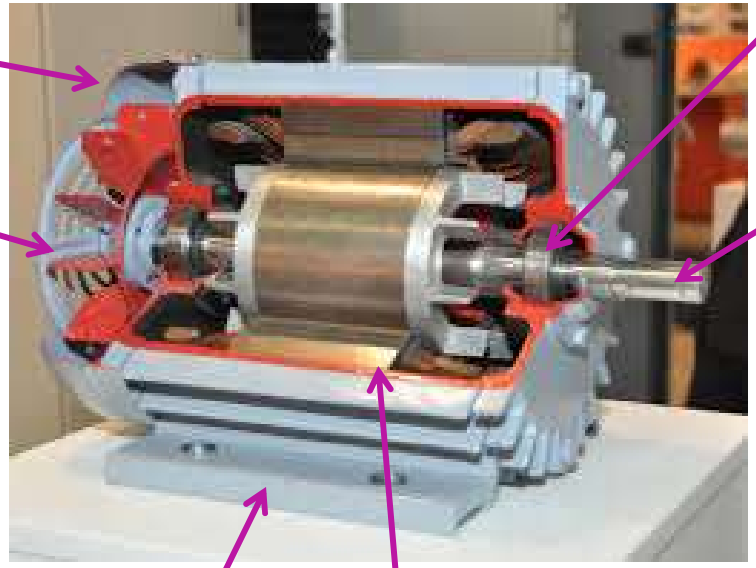
Some exist due to undesired effects.

Cover Electric Power to Rotary Power

Primary and secondary functions

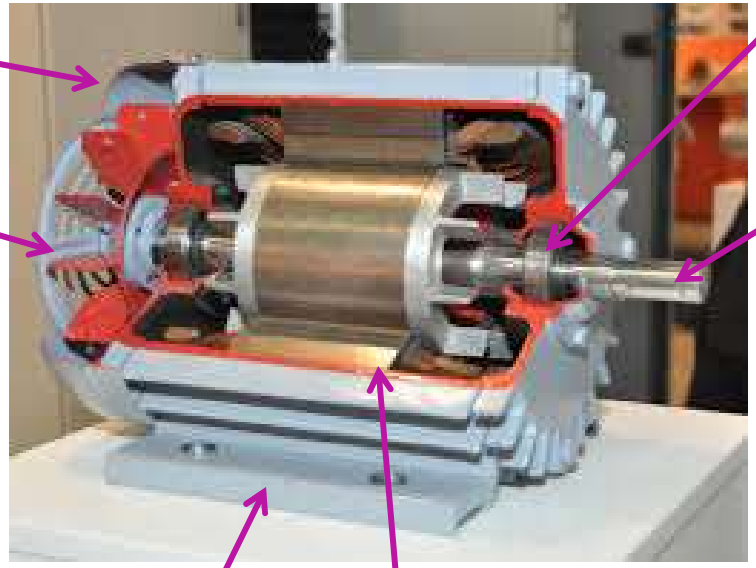
Not all functions exist to generate customer satisfaction.

Some exist due to undesired effects.



Primary and secondary functions

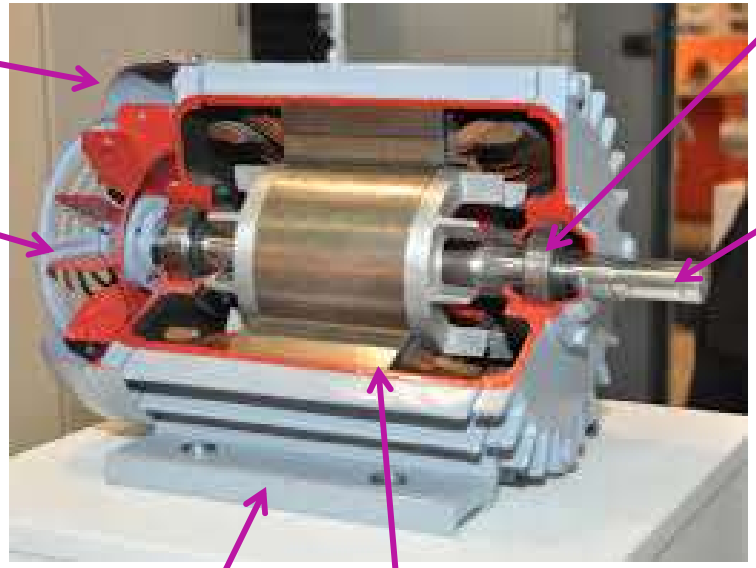
Determine by subtract-and-operate.



Primary and secondary functions

Not all functions exist to generate customer satisfaction.

Some exist due to undesired effects.



Input Electricity

Provide cooling

A ***secondary function***. It only exists because of our poor solution to the primary functions. The windings overheat.

Allow rotation

Transmit rotation

Clamp rotation

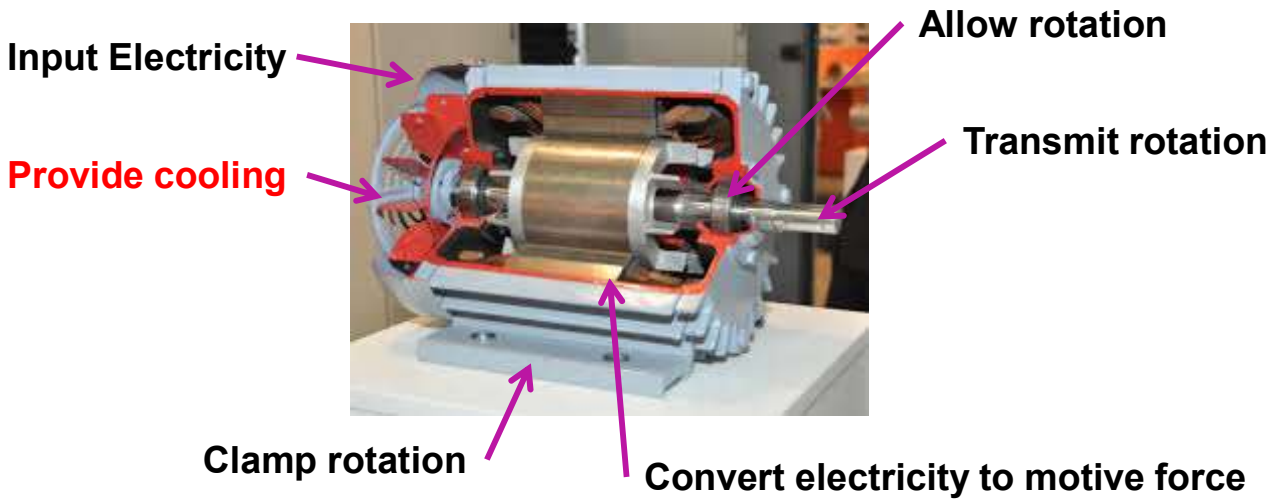
Convert electricity to motive force

Primary and secondary functions

What are ideas to eliminate the fan?

Why does the fan exist?

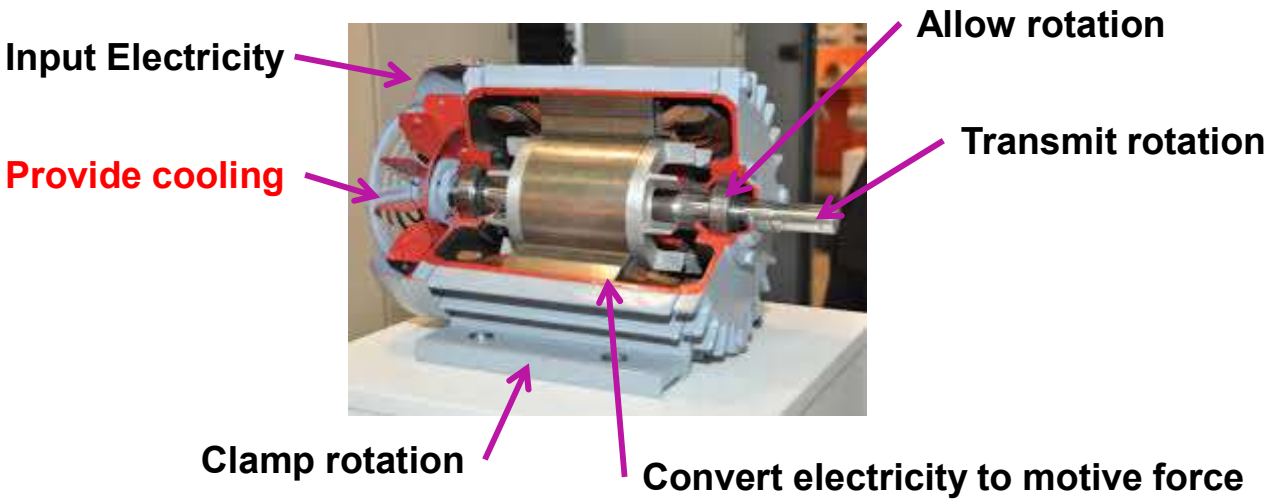
- To cool the windings. Windings do the 'convert elec to motive force'



Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?



Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

2 methods

- Itself method
- Freely available resource method

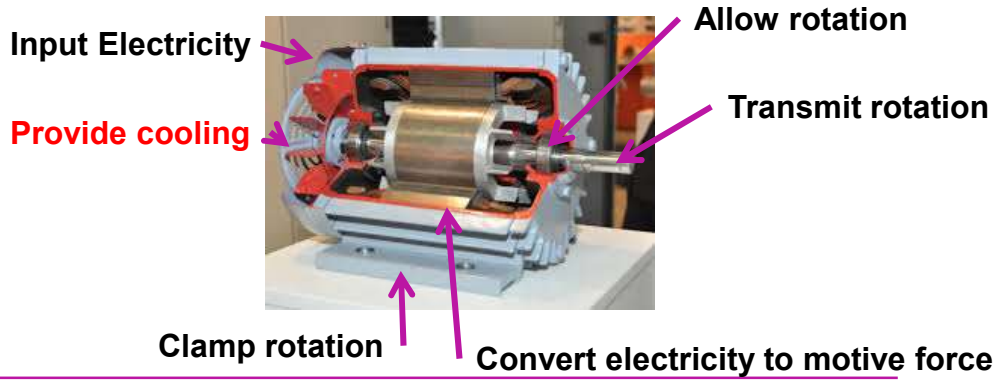
Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

Itself method

The tool functions the object.



Primary and secondary functions

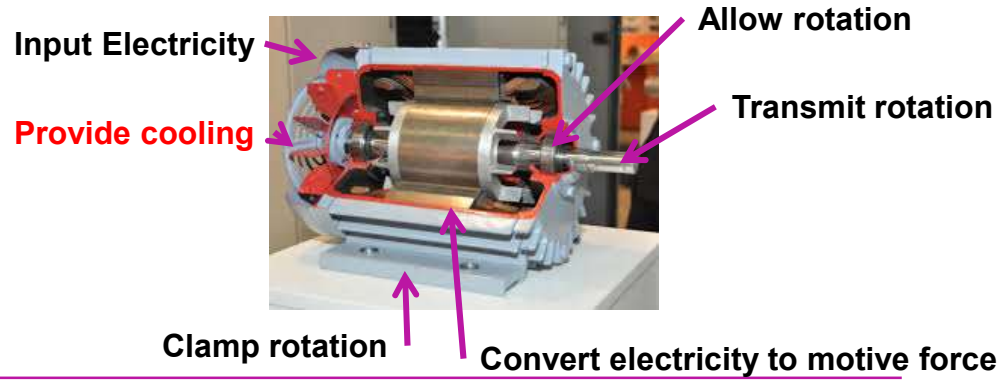
What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

Itself method

The tool functions the object.

The fan cools the motor windings.



Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

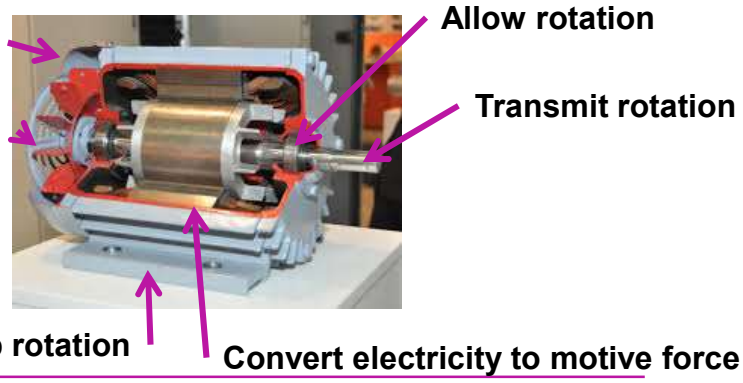
Itself method

The tool functions the object.

The fan cools the motor windings.

Can we make object function?

Can we make windings cool?



Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to 'convert electricity to motive force' without 'provide cooling'?

Itself method

The tool functions the objec

The fan cools the motor win

Can we make object functio

Can we make windings cool

Concept: Eliminate losses:
Part load loss.
Match Voltage (elec power) to load power. VFD.

Concept: Eliminate winding electrical resistance
Supercooling

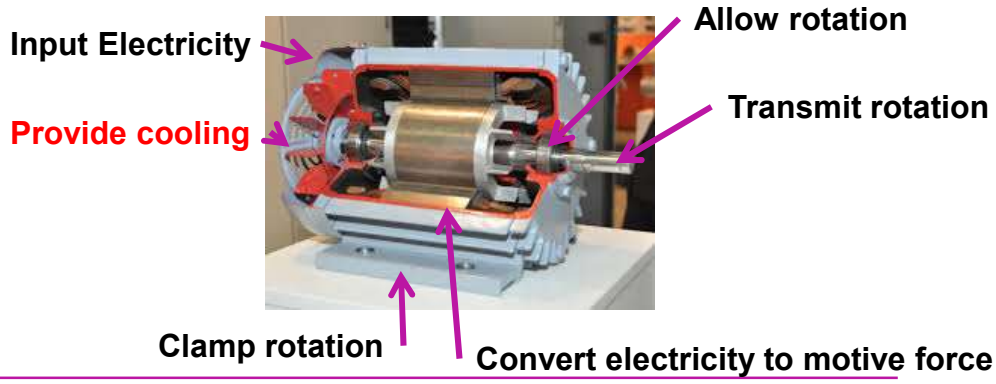
Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

Freely Available Resource method

What resources can be used to function?



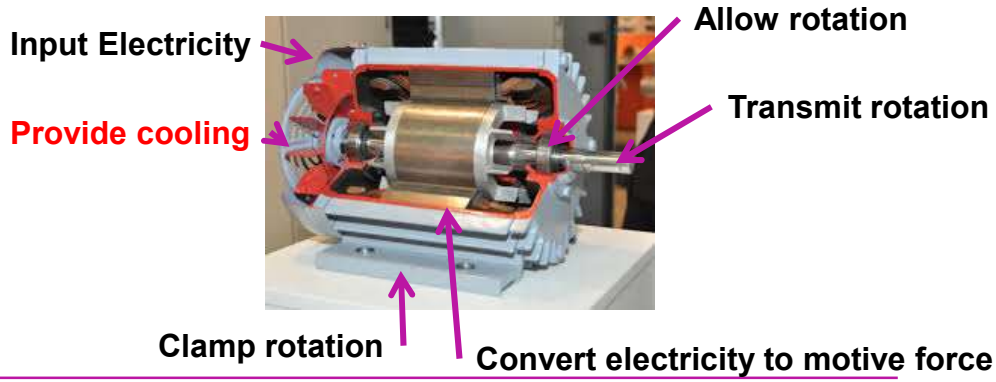
Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

Freely Available Resource method

What resources can be used to cool?



Primary and secondary functions

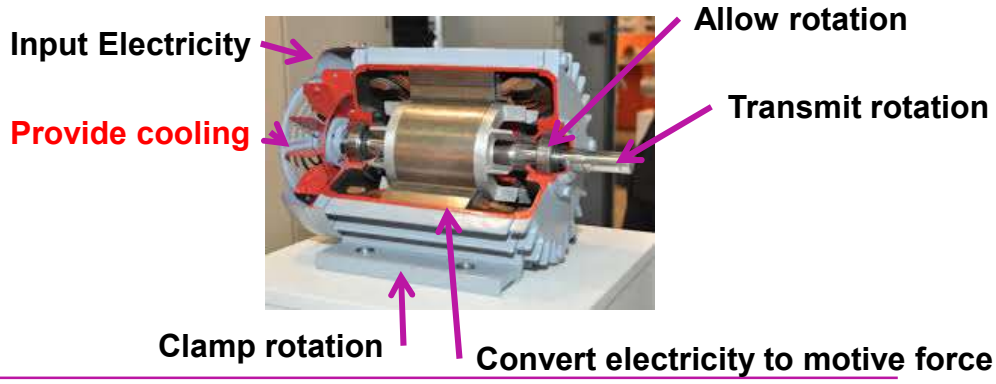
What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

Freely Available Resource method

What resources can be used to cool?

- Ambient Air
- Frame
- Whatever is being rotated



Primary and secondary functions

What are ideas to eliminate the fan?

- What are ways to ‘convert electricity to motive force’ without ‘provide cooling’?

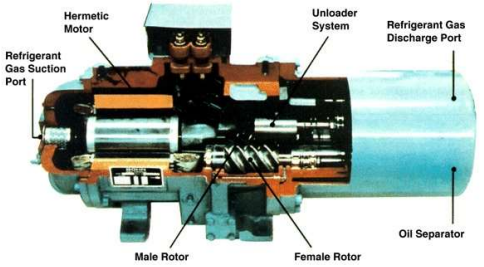
Freely Available Resource r

What resources can be use

- Ambient Air
- Frame
- Whatever is being rotated

Concept: Buoyancy Cooling:
Add passive cooling heat exchanger that drive hot air up

Concept: Working fluid
Use the pumped fluids to cool



Clamp rotation

Convert electricity to motive force

Summary

Analyze for new concepts which can implement the ideal result: use the result to provide the functionality without the system

- This can be done at all levels: product, subsystem, component

Analyze for new concepts which can make use of freely available resources, and use those resources to provide the functionality without the system

- This can be done at all levels: product, subsystem, component

Analyze for eliminating secondary functions

Homework Exercise

1. List the overall function and at least 6 sub-functions of your device. Pick a sub-function to further analyze and list.

- **State which parts are necessary, and why: to what customer need do they provide functionality,**
- **State which parts are secondary, there only to solve a problem with a necessary function.**

2. For one secondary part, generate ideas for eliminating it: a new way to provide the necessary function without the secondary parts. Use both the IFR and/or freely available resource approaches. Provide annotated sketches and a few sentences of explanation.