GE105
Introduction to Engineering Design
College of Engineering
King Saud University

# Lecture 10
# Concept Generation and Evaluation

2014-2015

## Introduction

So far you should know how to:

- Interpret the needs and analyze them
- Specify the objectives (primary and secondary)
- Determine the human factors
- Formulate the constraints and criteria
- Conduct morphological analysis and generate concepts.

Today you will learn how to:

- Evaluate alternatives through the **weight-and- rate** technique

This will be covered through a "solar oven" design example

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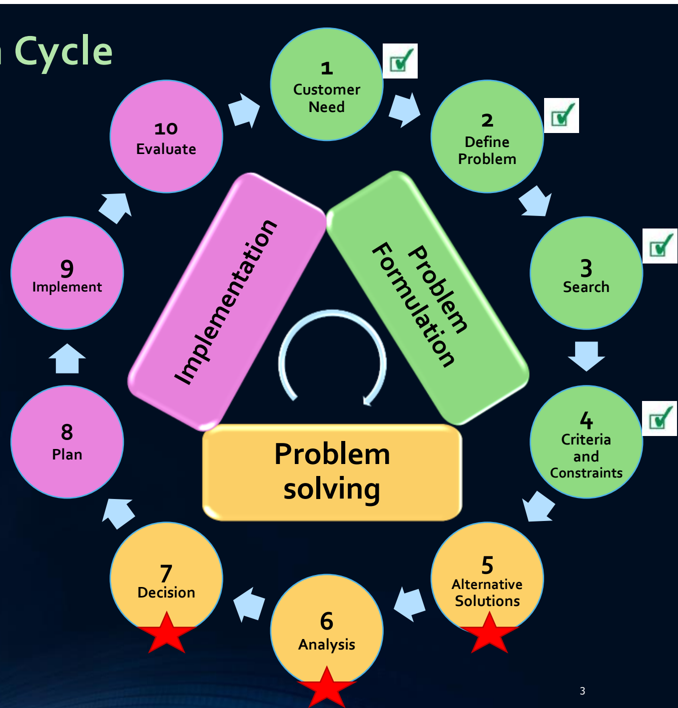
## The Design Cycle

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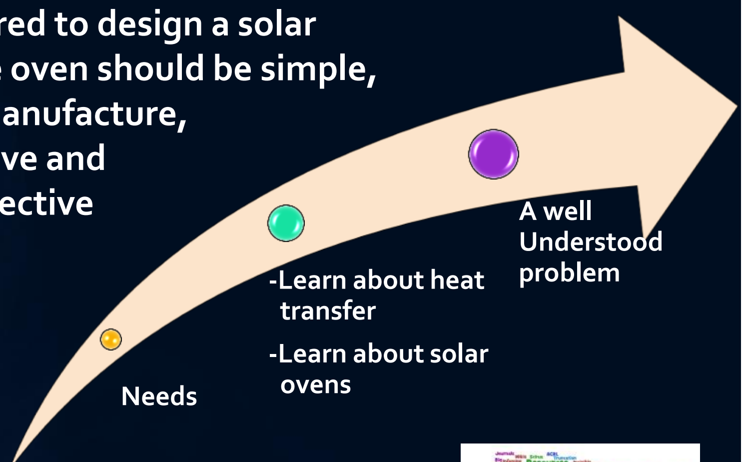
## The Solar Oven Example

It is required to design a solar oven. The oven should be simple, easy to manufacture, inexpensive and highly effective




The first step is not about finding solutions; It is about understanding the problem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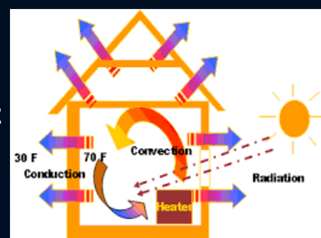
## Heat Transfer

It occurs through one of three modes when a $\Delta T$ exists

1. Conduction: Heat travels from atom to atom of a solid
   Example: Doorknob is hot if fire is on other side
2. Convection: With a gas or liquid, the heat propagates as molecules move
   Example: When you open the door of an oven, the temperature in the kitchen increases
3. Radiation: A heated surface emits electromagnetic waves which carry energy away from the emitting object
   Example: Heat felt from a brick wall that has been in the sun all day

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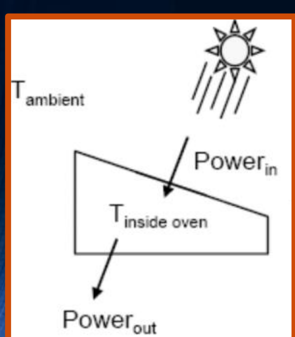
## Understanding the Problem

$$\Delta T = T_{inside\ oven} - T_{ambiant}$$




**Crireria:**

- **Maximize $\Delta T$**
- **Minimize Cost**

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## Key Ideas

- Sunlight contains energy
- You want a solar oven that gets as hot as possible (highest temperature in oven chamber)
- You want your oven to receive solar energy easily
- You also want your oven not to lose the solar energy it has captured

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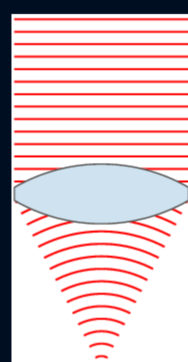
## Specifications

- Low Cost
- Maximum Temperature
- No lenses
- Size of chamber (partition)
- No preheating
- Presence of a thermometer
- Simplicity
- …



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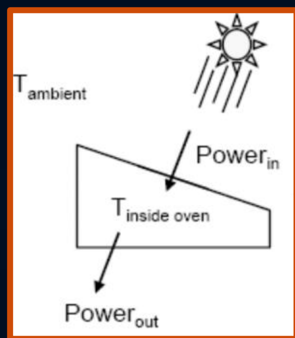
## Solar Oven Heat Transfer

$$\Delta T = T_{inside\ oven} - T_{ambiant}$$

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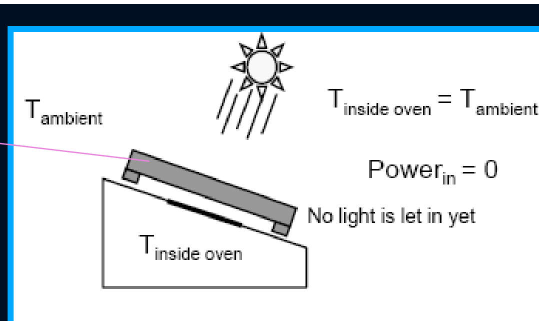
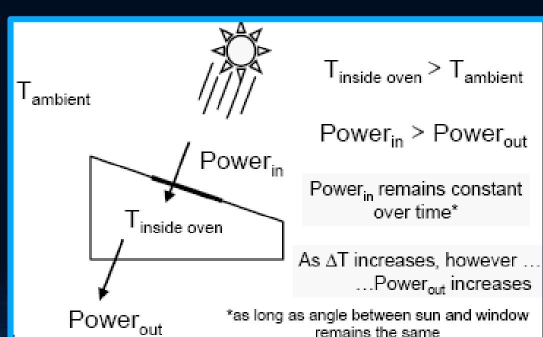
**Time = 0**

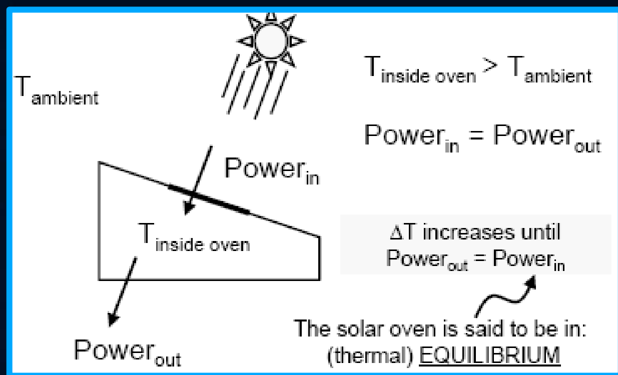
Cover




**Time = Shortly after Cover Removed**



## Time = a long time after “0"

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## Summarizing what we know

- We want the largest ΔT we can get for a given cost
- To get a larger ΔT, we need either to:
  1. Increase Power in (get more sun into the oven)
  2. Decrease Power out for a given ΔT (reduce the rate at which energy is leaving the oven)

$$\uparrow \Delta T = \uparrow T_2 - T_1$$

$$\uparrow \Delta T = T_2 - \downarrow T_1$$

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## Increasing Powerin

**Solar Intensity=1000 W/m$^2$**

↓

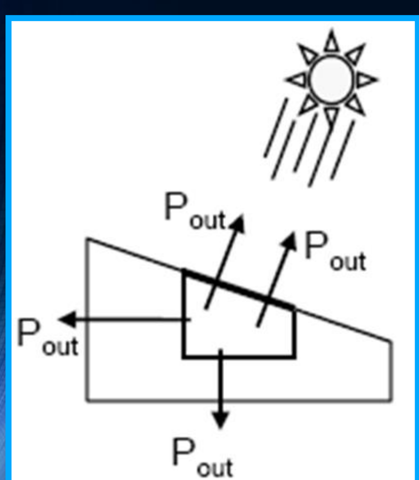
**Increase the area**

What determines Power$_{in}$:
- Window Size
- Sun Intensity
- Window Thickness
- Angle light hits window
- Color of oven Wall

To increase Power$_{in}$ :
- Bigger window
- Thinner window



## Decreasing Powerout for a given ΔT?

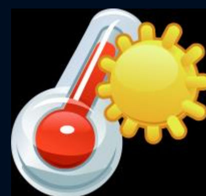



Energy leaves the oven through:
- Radiation
  (back out window)
- Conduction and Convection
  - back out window
  - sides of oven
  - bottom of oven

## Decreasing Powerout for a given ΔT?

Heat Transfer Via Window

- About 25 W /(m² °C) when T inside oven=150°C
- About 12 W/(m² °C) for a thicker window



Heat Transfer Via Sides and Bottom

- About 1.5 W/(m² °C)

More heat is lost through window

- Therefore, you want a smaller, thicker window to keep heat in!
- Some good insulation on sides and bottom

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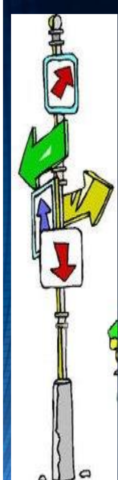
## Putting it all Together



- To increase Power$_{in}$
  - Increase window size
  - Decrease window thickness
- To decrease Power$_{out}$
  - Decrease window size
  - Increase window thickness
- Conflicting objectives? well, this is Engineering Design; you must make trade-offs (a compromise)

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## Solar Oven Concept Generation (Brainstorming)

No Reflector

Single Flat Reflector

Parabolic

4 Flat Reflectors Open Corners

4 Flat Reflectors Closed Corners

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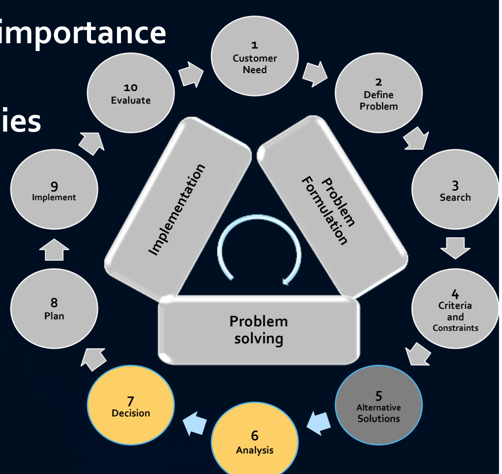
## Concept Evaluation

- Characteristics of Engineering Decisions
  - Multiple criteria
  - Criteria are of different importance
  - Criteria are conflicting
  - Multiple interested parties

- **Use a Decision Matrix:** A simple decision approach to weigh pros and cons applying **weight and rate** concept (**multiply and sum**)

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## Applying weight-and-rate

- Features/attributes of the solar viewed important:
  - ✓Direct Energy into Oven
  - ✓Easy to Manufacture
  - ✓Room for Error in Aim
  - ✓Hold Energy in Oven
  - ✓Durable
  - ✓…

- Keep attributes as independent as possible!

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## Weights

- To determine the importance of each attribute, we use a simple approach based on weights that sum to 100

| | Direct Energy | Manufacturability | Flexibility | Holding Energy in Oven | Total Weight |
|---|---|---|---|---|---|
| Scenario 1: Compromise | 25 | 25 | 25 | 25 | 100% |
| Scenario 2: Most light in | 40 | 5 | 15 | 40 | 100% |
| Scenario 3: Easy to make | 20 | 40 | 20 | 20 | 100% |

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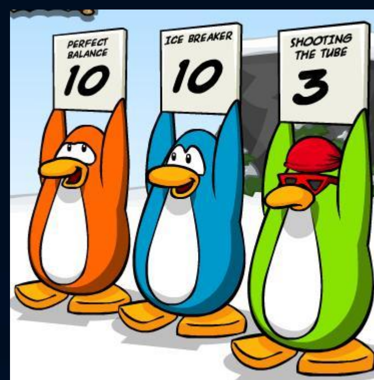
## Rates

- Once alternative concepts are determined, rate each attribute for each alternative concept on a scale from 1 (worst) to 10 (best)
- For the solar oven example, we will only use three alternative concepts and four attributes
- Normally, you would have more concepts and more attributes






## Rating the Concepts

- Let us use the "most light in" Scenario
- This scenario uses weights (40,5,15,40)

| | Direct Energy | Manufac turability | Flexibility | Holding Energy in Oven | Score |
|---|---|---|---|---|---|
| Weights→ | 40 | 5 | 15 | 40 | |
| Concept 1: No reflector Big window | 1 | 10 | 5 | 3 | 285 |
| | 40 | 50 | 75 | 120 | |
| Concept 2: 1 reflector Small window | 4 | 8 | 7 | 6 | 545 |
| | 160 | 40 | 105 | 240 | |
| Concept 3: Parabolic | 9 | 2 | 4 | 4 | 590 |
| | 360 | 10 | 60 | 160 | |

## Rating the Concepts

- Let us use the "compromise" Scenario
- This scenario uses weights (25, 25 , 25, 25)

| | Direct Energy | Manufac turability | Flexibility | Holding Energy in Oven | Score |
|---|---|---|---|---|---|
| Weights→ | 25 | 25 | 25 | 25 | |
| Concept 1: No reflector Big window | 1 | 10 | 5 | 3 | 475 |
| | 25 | 250 | 125 | 75 | |
| Concept 2: 1 reflector Small window | 4 | 8 | 7 | 6 | 625 ★ |
| | 100 | 200 | 175 | 150 | |
| Concept 3: Parabolic | 9 | 2 | 4 | 4 | 475 |
| | 225 | 50 | 100 | 100 | |

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## Final Remarks

- **Decision matrices (weight-and-rate) are helpful tools for exploring trade-offs**
- **Use more than one scenario and do not be driven by a single-objective mentality**
- **You do not necessarily have to use the one with the highest score**

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