GE106
Introduction to Engineering Design
College of Engineering
King Saud University

Lecture 10.

Concept Generation and Evaluation

FALL 2022

Introduction

So far you should know how to:

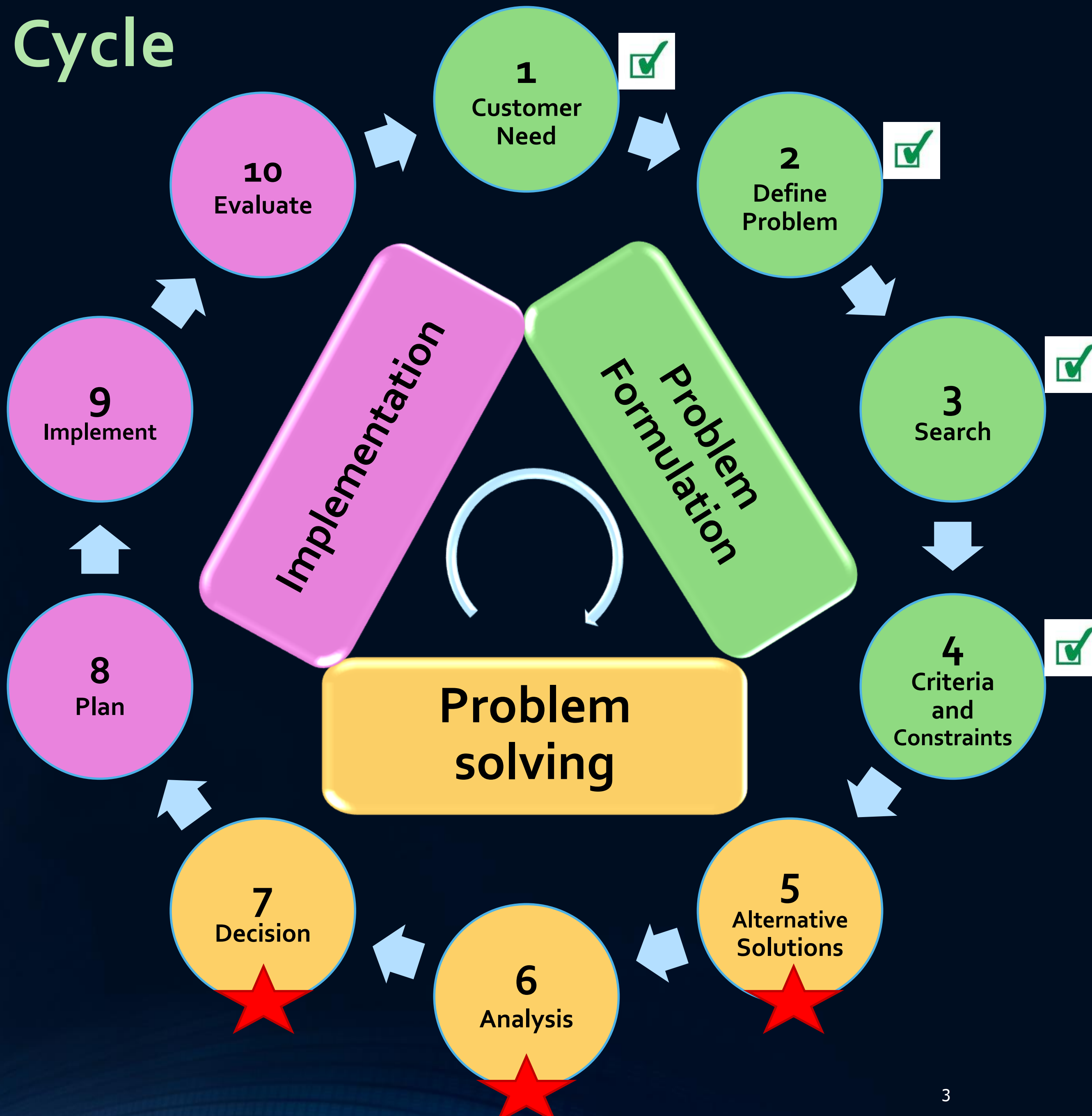
- Interpret the needs and analyze them
- Specify the objectives (primary and secondary)
- Determine the human factors
- Formulate the constraints and criteria
- Conduct a morphological analysis and generate concepts.

Today you will learn how to:

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

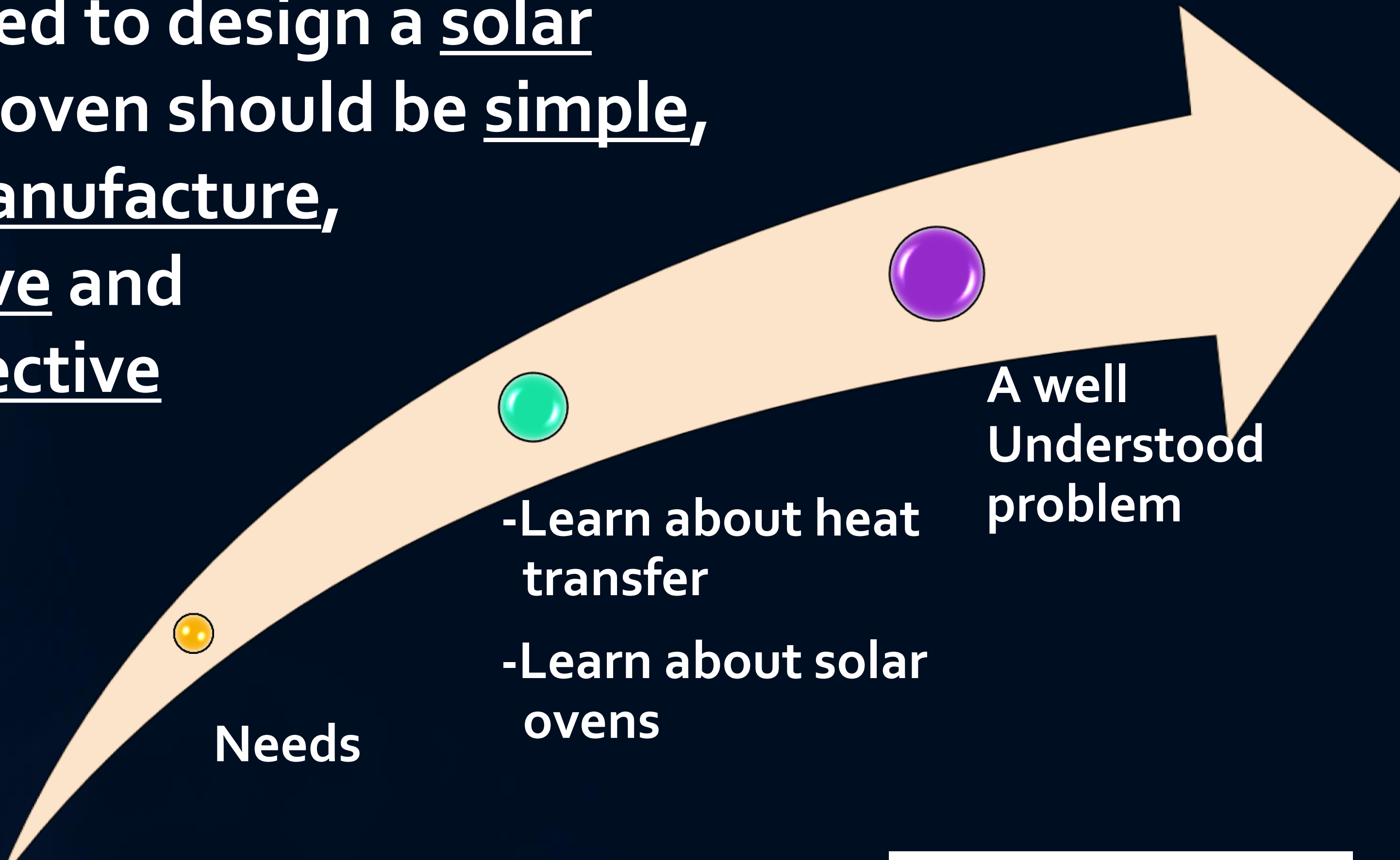
This will be covered through a "solar oven" design example

The Design Cycle



The Solar Oven Example

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



Needs

-Learn about heat transfer

-Learn about solar ovens

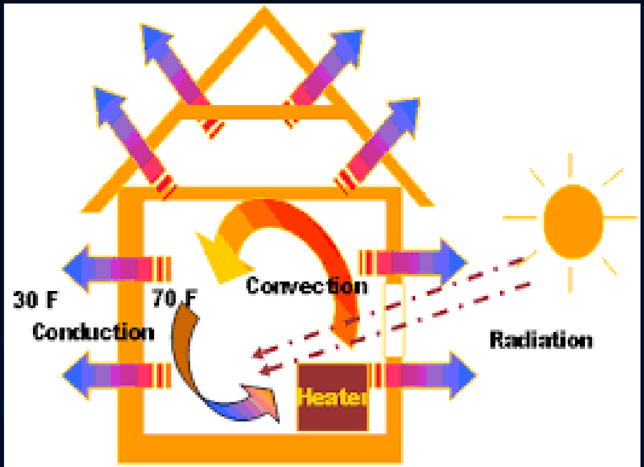
A well Understood problem

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

Heat Transfer

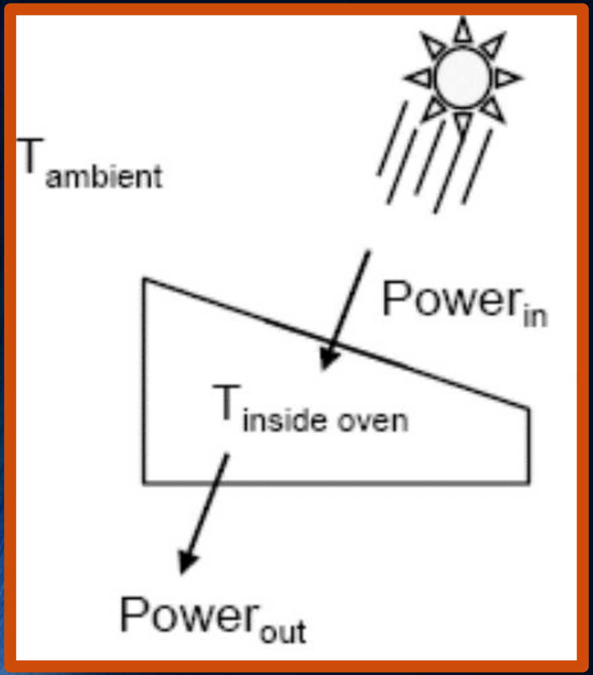
It occurs through one of three modes when a ΔT exists

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



Understanding the Problem

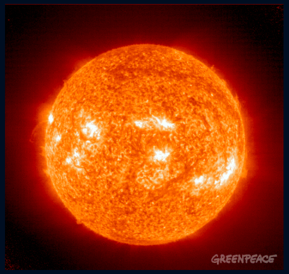
$$\Delta T = T_{inside\ oven} - T_{ambient}$$



Criteria:

- **Maximize ΔT**
- **Minimize Cost**

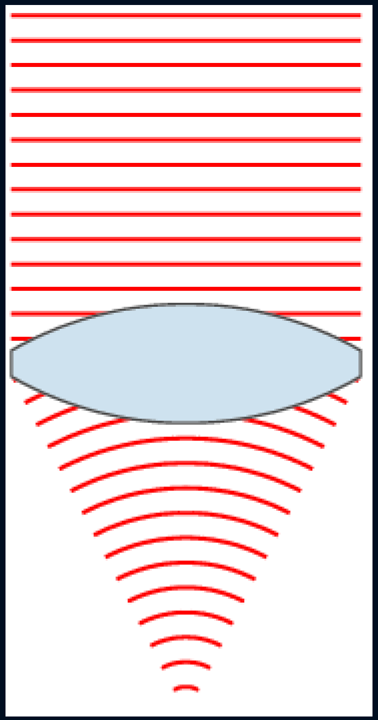
Key Ideas



- 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

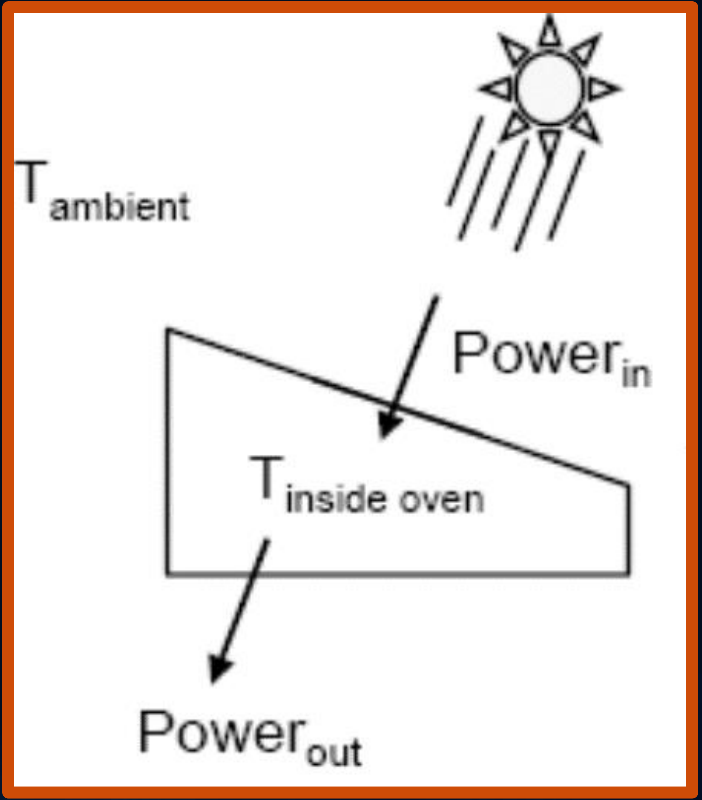
Needs

- Low Cost
- Maximum Temperature
- No lenses
- Size of chamber (partition)
- No preheating
- Presence of a thermometer
- High simplicity
- ...



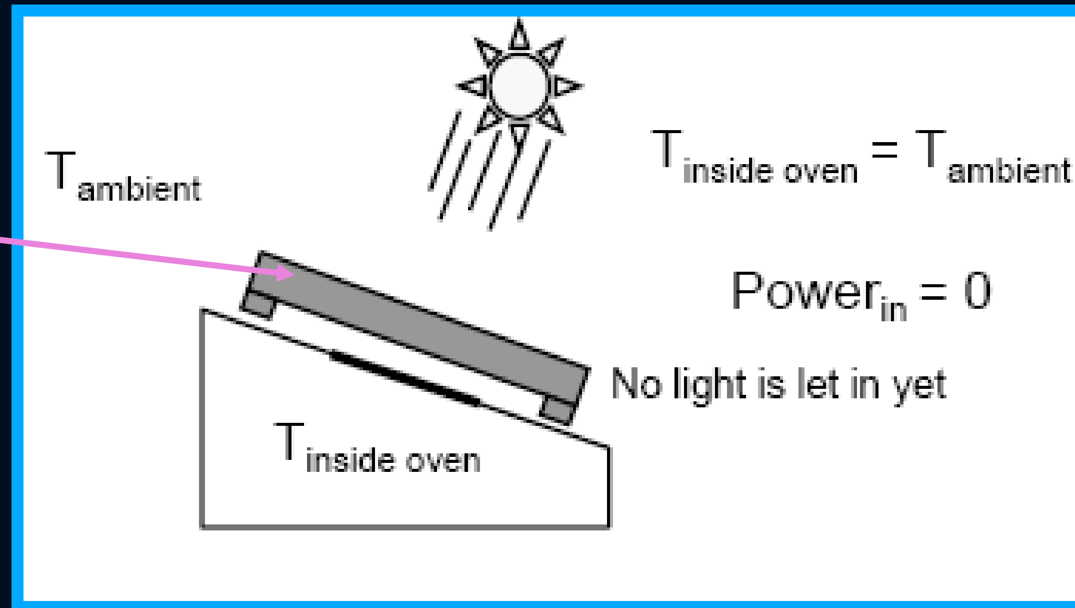
Solar Oven Heat Transfer

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

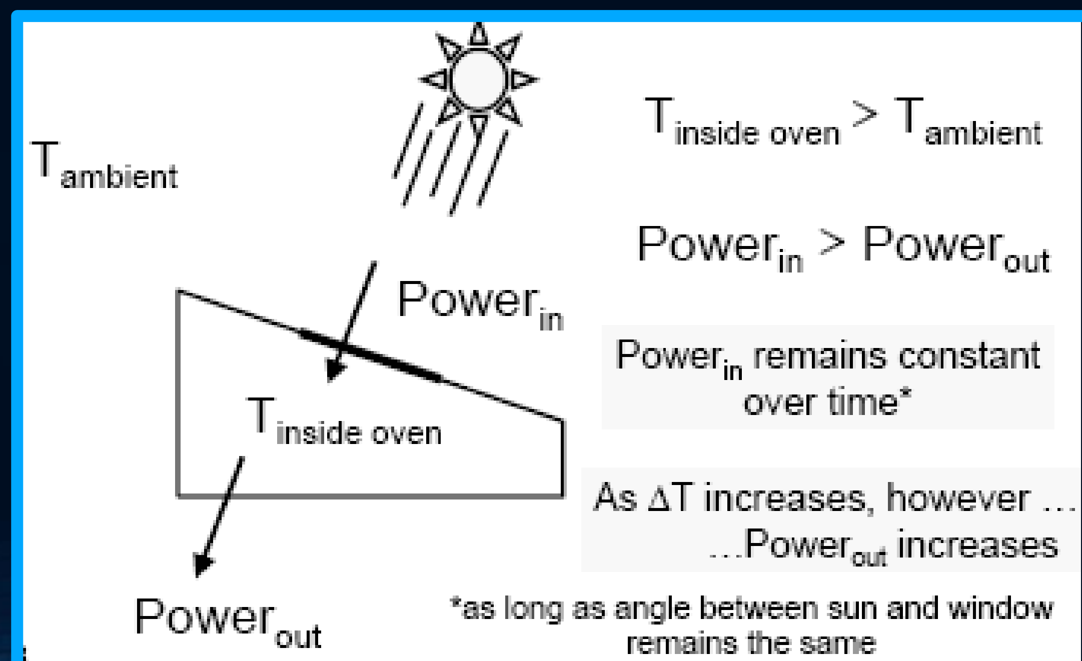


Time = 0

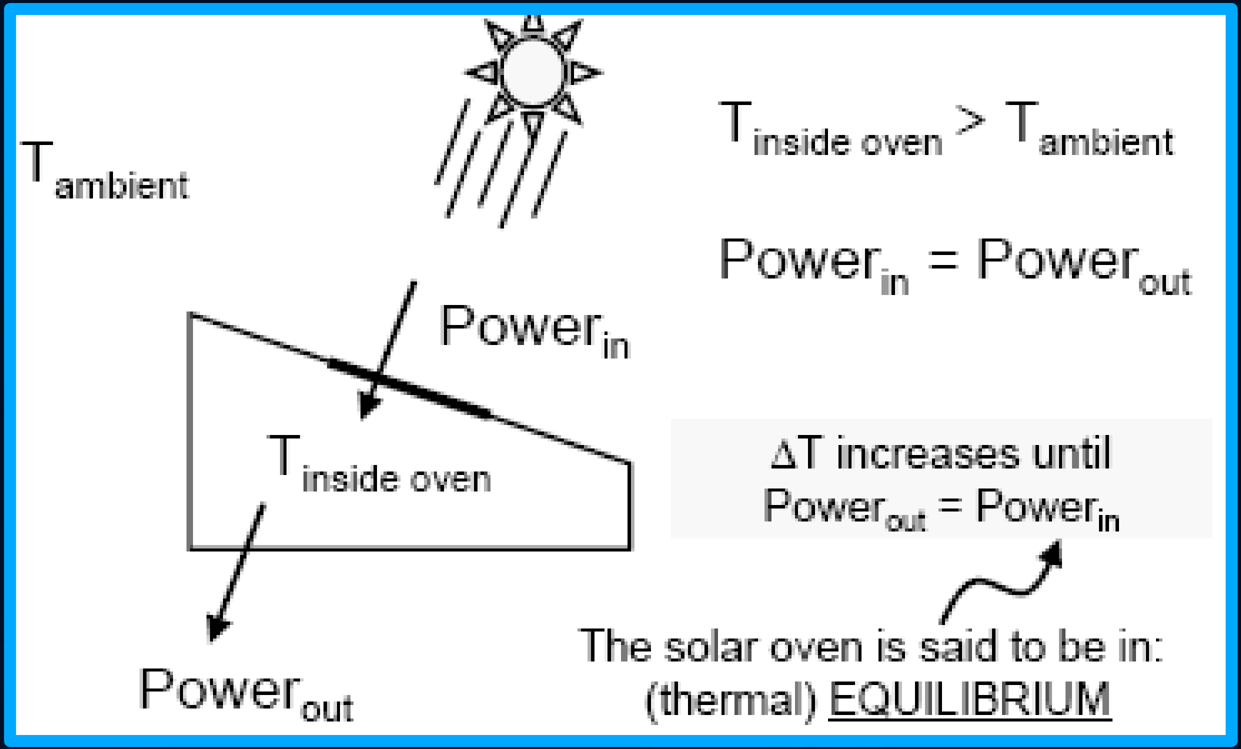
Cover



Time = Shortly after Cover is Removed



Time = a long time after “0"



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)

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

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

Increasing $Power_{in}$

Solar Intensity = 1,000 W/m^2

↓

Increase the area

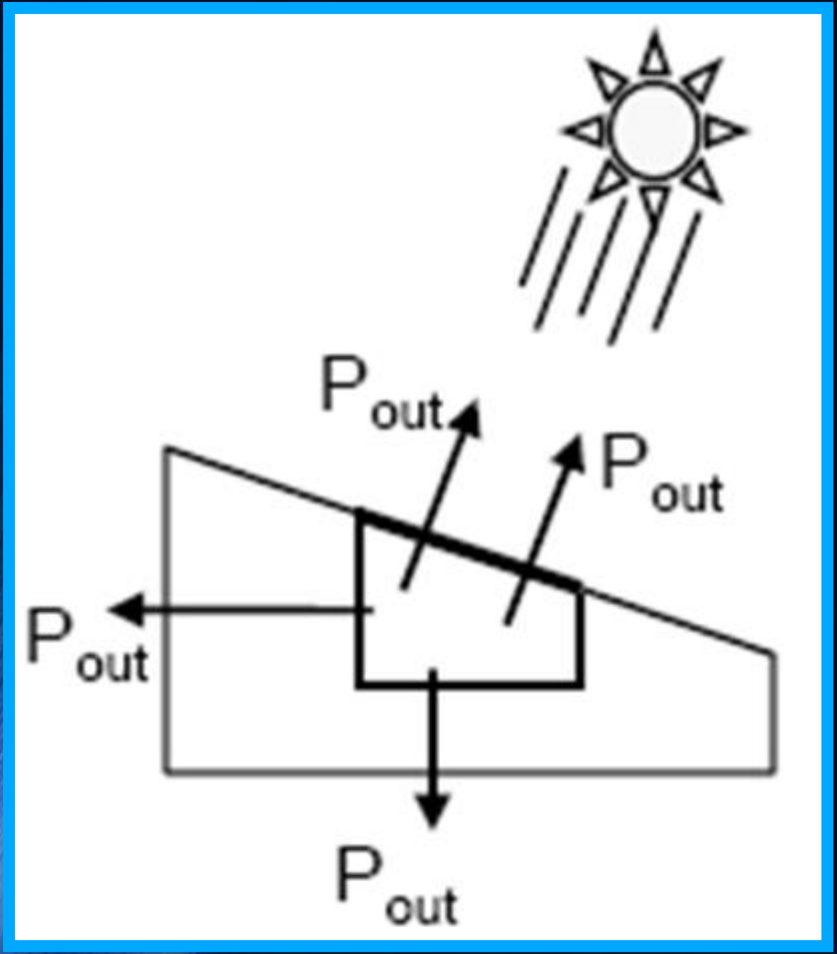
What determines $Power_{in}$:

- Window Size
- Sun Intensity
- Window Thickness
- Angle light hits window
- Color of oven Wall*

To increase $Power_{in}$:

- Bigger window
- Thinner window*

Decreasing $Power_{out}$ 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 Power$_{out}$ 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

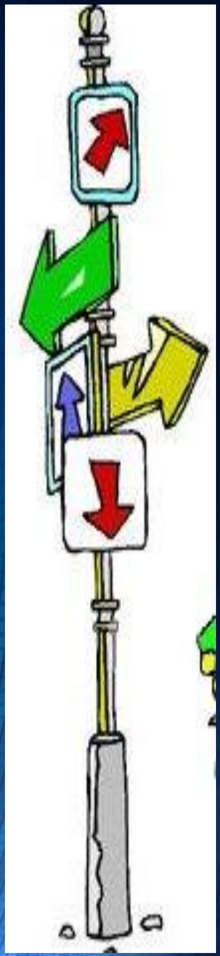
Heat Transfer Via Sides and Bottom

- 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

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 tradeoffs (compromise)

Solar Oven Concept Generation (Brainstorming)

No Reflector

Single Flat Reflector

Parabolic

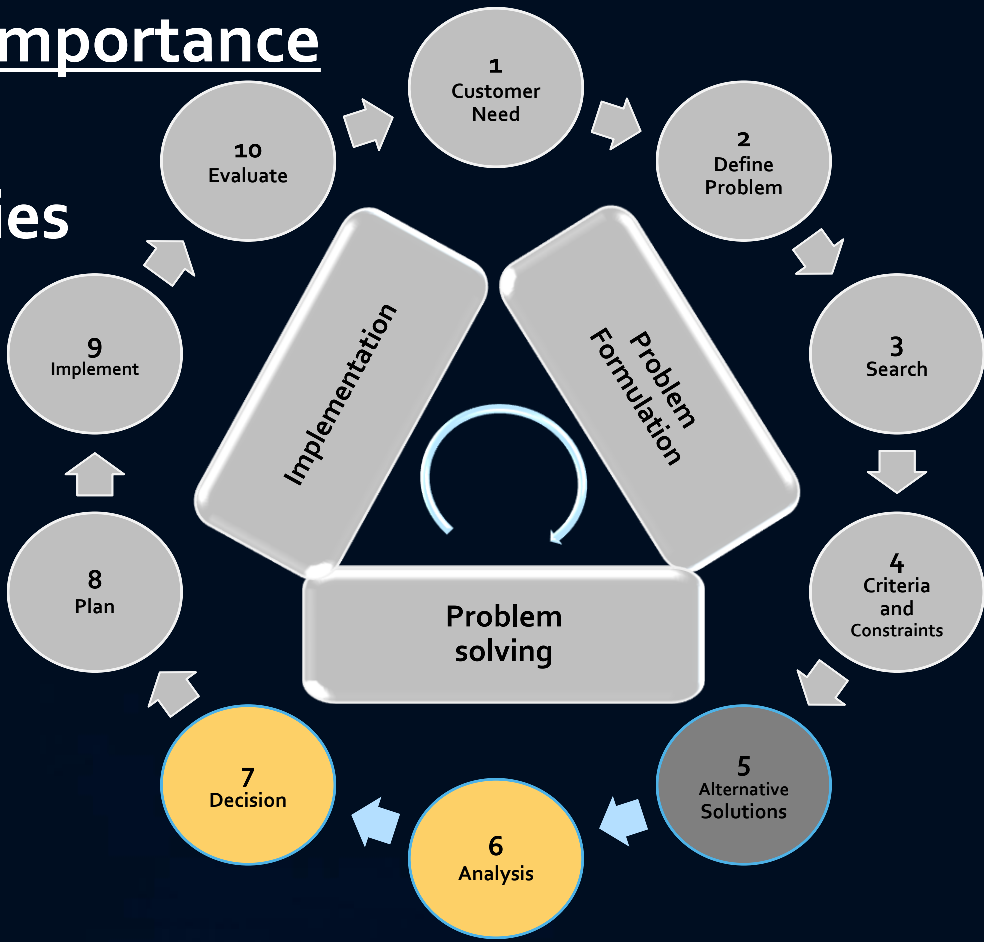
4 Flat Reflectors Open Corners

4 Flat Reflectors Closed Corners

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)



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!*

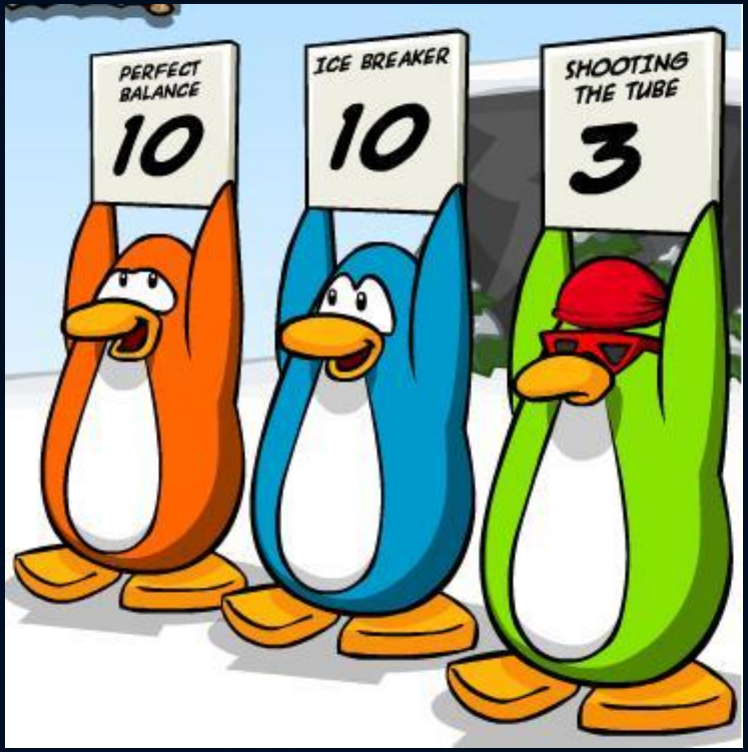
Weights

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

	Direct Energy	Manufac turability	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%

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	

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