MECH 3200 – 15F

**Concept Creation**

Prerequisite: Engineering Design Specification (EDS)

“The motivation for applying any creativity technique to a design task is to generate as many ideas as possible. Quantity counts above quality, and wild ideas are encouraged at the early stages of the design work.” – Dieter & Schmidt 5e., p.212

“...it is critical to get 30 to 40 ideas...” - Dieter & Schmidt 5e., p.203

Freud’s Brain Model:
- Conscious Mind – Processor, RAM
- Preconscious mind – Stored memory
- Subconscious mind – Machine intelligence (operates during screen-saver mode)

Creative Process Steps:
- Preparation – Embed the problem (day 1)
- Incubation – Let your subconscious go to work on it (that night).
- Inspiration – Conscious mind retrieves the result (day 2).
- Verification – Conscious mind organizes the result (day 3).

The catch:
- Your subconscious is sloppy.
- Retrieval and organization take significant effort.
- Hence need for creativity methodology.

Get ready to think creatively:
- Confidence – You are as good as most of the engineers you will ever meet, and therefore can expect yourself to perform as well on any specific engineering task.
- Persistent – No one said it was easy.
- Imagination – See wild above.
- Open mind – If you’re focusing on one answer, that’s all you will ever get.
- Non-Judgmental – I.e., judge ideas later. For now, let the sparks flame up a little.
- Boundaries – Focus on the problem statement.

Purge yourself of wrong thoughts:
- Stereotyping – Allow multiple associations to each object/idea
- Information overload – Make sure you’re looking at the big picture
- Limiting – Allow maximum solution space
- Fixation – Don’t allow 1-D solution space
- Conformity – Don’t use someone else’s solution space
- Risk avoidance – I.e., sounding silly. Engineers are not silly. Except for in concept generation. So enjoy it while you can. Studies prove that it works.
• Chaos avoidance – Expansion (of solution space) is an entropy-generating process – it must be so.
• Cramming – Per “Steps” above, must allow time to sleep on it.
• Careless – Hard to design something you won’t care about.
• Tripping over the language – Try: graphics; flowcharts; outlines; math; text
• Memory block – Try to find another RAM-to-storage interface.
• Don’t know nuthin’ ‘bout… – See DK notes
• Bad data – Are you sure that everything you know is right?
• Bad environment – By looking at your concept ideas, can you tell what TV show you were watching?
• They will laugh at me – Suck it up and just do it until you have enough confidence.

Ideation
• Sensitivity – The Customers’ problem exists.
• Fluency – Your job is to dream up solutions.
• Flexibility – Your job is to dream up many and varied solutions.
• Originality – For design engineering, this is a legal requirement.

Importance of multiple solutions:
• There are way more ways to do things than you first imagine.
• At least a few of the ways are better than what you first imagine.
• The way you first imagine one feature might not fit well (in the overall design) with the way you first imagine another feature – and so you need a range of ideas to act as back-ups (i.e., need catalog of ideas).

Creative Methodology
• Flash of insight
  o Necessary, but not sufficient!
  o Great starting place, but the flash is an idea that remains to be proven against the CR’s, and always needs lots more development
  o Note: flashes are easier if the flasher has a wide range of DK – the subconscious works better that way.
  o Über-deep DK can be counter-productive – tends to bias the designer – hard to say where critical range and critical depth boundaries are.
  o When the ideas stop, try SCAMPER:
    ▪ Substitute
    ▪ Combine
    ▪ Adapt
    ▪ Modify, Magnify, Minimize
    ▪ Put to other uses
    ▪ Eliminate
    ▪ Rearrange, Reverse
  o Or do Random Input
    ▪ Choose a random word (choose randomization process first)
- Associate Problem with the word
- Associate other ideas with the word
  - There are no bad ideas – every one is written down
  - Record (or draw) all the ideas
  - And then incubation period (i.e., sleep)
  - And then Feasibility Triage (evaluation)
    - OK ideas (explain why)
    - Ideas that can be OK with help (explain and fix)
    - Ideas that just cannot be feasible (do post-mortem to figure out why, and if there are any salvageable parts)
    - “Affinity Diagram”
- Brainstorming (group flashing – group produces ideas to meet CR’s)
  - Group needs diversity [both people with depth in design area and people without depth – also, opportunity for concurrent engineering with users, manufacturers, and distributors represented (but don’t make group too big!)]
  - Leader acts as moderator, suggester of CR’s, organizer of ideas, not so much generator of ideas
- Brainwriting (group development of flash results)
  - Method 635 (6 people, each develop 3 concepts, pass them to next person who adds 3 new concepts, complete the passing circuit 5 times)
  - Gallery (635 without linear passing – each concept is posted, and group members wander around adding onto or developing as they like)
- Synectics
  - Direct analogy (example – a machine that picks up bearing balls without scratching them has a lot of similarities to an apple-picking machine)
  - Fantasy analogy (Wouldn’t it be cool if…)
  - Personal analogy (Anthropomorphication)
  - Natural system analogy (Biomimicry - very good for rigid and compliant structures, natural heat convection, gravity-powered fluid flows, surface tension-powered fluid flows).
  - Symbolic analogy (express the problem and ideas in another language – e.g., graphical, math, etc.)
  - Similar product dissection (take apart an existing device to back-figure it’s functionality. Very dangerous! Often biases designers toward a narrow solution space!)
- Concept Map (with graphics - a doodle sheet)
- Discursive (analytical, non-intuitive – needs flash to drive initial stage)
  - Derive solution space.
  - Example: diving board, assume hollow shell configuration – mostly a matter of finding the structural arrangement of the internal cross section
\[
\frac{P}{\delta} = \frac{3EI}{l^3}; \quad I \approx \frac{1}{2}wh^2 \quad \Rightarrow \quad \frac{P}{\delta} = \frac{3Ewh^2}{2l^3}
\]

\[
W = 2wlt\rho; \quad \frac{E}{\rho} \sim \text{constraint}
\]

\[\Rightarrow \text{optimize } W \text{ subject to } \frac{P}{\delta} \text{ constraint}\]

- Nomenclature:
  - \(P\) – tip load (max body weight), kg
  - \(\delta\) – tip deflection, m
  - \(E\) – elastic modulus, a material constant, N/m²
  - \(\rho\) – density, a material constant, kg/m³
  - \(l\) – board length, m
  - \(I\) – board cross section’s area moment of inertia (resistance to bending), m⁴
  - \(w\) – board width, m
  - \(h\) – board thickness, m
  - \(t\) – board skin thickness (assumes board has structural shell and soft core), m
  - \(W\) – board weight (probably proportional to cost), N – EC
  - \(E/\rho\) – fixed by material choice, m²/s² – EC
  - \(P/\delta\) – spring constant (“springiness”), N/m – EC

- Continuous variation in parameters automatically fills solution space
- Can mathematically identify design success
- A design surface might result – plot of weight v. cost or weight v. performance (or performance v. cost) – means that discursive analysis finds that two EC’s are not independent.
- Classification of results
  - Rigorously identify best concepts by covering all possible variations
  - Example: internal combustion engine
    - Cycle: 2 stroke – 2S; 4 stroke 4S
    - Ignition: spark ignited – SI; compression ignited – CI
    - Cylinder Arrangement: inline – I; vee – V
    - Cooling System: air cooled – A; liquid cooled – W

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Result: 16 unique overall concepts to be evaluated

Multiple Solutions Example:
Several means for converting rotational motion into linear motion

Independence of solution alternatives
‘Multiple’ is not meaningful unless the working principles are truly different.