• 50 minutes, 3 problems, 30 points, weighted as marked.
• Closed book. Closed notes, except for one side of one 8½ × 11 in. page.
• Unlimited blank scratch paper is allowed.
• Turn in only the attached exam papers.
• Do not detach any of the exam papers.
• Do not write on the backs of the exam papers. Backs WILL NOT be scored. (Work answers on backs or on scratch paper; then write final result onto test paper).
• Your objective is to demonstrate your command of the course subject matter. Your goal is not merely to answer, but to answer well.
1. (10 points) Problem Definition. Consider a Tension Leg Platform used for oil production in the North Sea. The TLP’s hull (floating part) is connected to its tendons (cables to the seabed) with steel pins, 10 cm in diameter, and 30 cm long. The pins are held in place with internal snap rings (very large, stiff, heavy snap rings). As part of periodic maintenance, the pins are to be removed. One step in this process is the removal of the snap rings by a diver. Keep in mind that the pin location is deep, the North Sea is cold, and the diver is severely physically impaired, as compared to a non-submerged worker.

Create a problem definition for the design problem of a tool that the diver can use to remove the snap ring. Suggest: users; needs; customer requirements; and engineering characteristics. Levels for engineering characteristics may be omitted. House of Quality rooms are not required.

Users:
- Diver (end user)
- Rig Manager (purchaser, project responsibility)

Needs:
- Diver
  - Easy to handle from surface to job site
  - Easy to operate
- Manager
  - Low cost impact on pin-removal operation
  - Low damage to surrounding parts

Customer Requirements:
- Easily transportable by diver belt or by work basket
- Easy to attach, engage, operate, and cycle to next operation
- Minimal effort to operate
- More cost-effective than surface tool (when used submerged)
- Low scraping potential
- Low indentation potential
- Snap ring actuation force (constraint)

Engineering Characteristics
- Weight
- Volume
- Cost
- Cycle time from one snap ring to the next
- Opposed force to operate (hand squeezing)
- Unopposed force to operate (arm pushing)
- Force to unintentionally disengage from snap ring
- Number of hands to operate
- Indentation pressure
- Scraping energy
2. (10 points) Functional Decomposition. Residential interior doors are sold at home supply stores as preassembled door-plus-frame units. To build these, the doors, frame pieces, and hinges are positioned and fastened (nailed or screwed) using hand labor. In years past, several AU/ME Comprehensive Design teams were devoted to the problem of automating this process. Create a functional decomposition for the overall function of ‘assemble framed door’ to about two levels of sub-function (each sub-function does not necessarily require sub-sub-functions; contrariwise, feel free to add sub-sub-sub-functions, if useful).
3. (10 points) Decision Matrix. A trench is to be cut in dirt, 30 ft. long, 1 ft. deep, and 6 in. wide, with hand tools. Moderately-sized roots are encountered in the digging (about 1.5 in. diameter). Consider the design problem of choosing an existing device to cut through these roots.

Customer requirements are:
- Trench must be straight enough that a PVC conduit can be laid into it, and then buried
- Budget for the greater project, of which the trench is a small part, is limited, and the trench should not cause significant additional expense
- Trench-digging volunteer labor time is limited (other project tasks need attention)
- It looks like there are a lot of roots

Solution concepts are:
- Sharpen the leading edges of the diggers’ picks and shovels
- Axe (and axe operator)
- Ditch Witch (powered trench-digging machine)

Create a decision matrix to evaluate these concepts

“lots of roots” isn’t really a CR – just an observation about the challenge of “trench must be straight”

Importances:
- Trench specs – high (no point if the PVC won’t drop in)
- Cost – moderate
- Labor time – moderate

Scores:
- Even with sharp picks, the trench floor won’t be too level (volunteer labor)
- Axe will mess up trench sides less than pick/shovel
- Ditch Witch will dig a perfect trench
- Sharpen edges is very cheap (assume tools exist)
- Axe will have to be acquired
- Ditch Witch will have to be rented and hauled to site
- With picks, labor intensive job
- A little less so with an axe
- Easy with a Ditch Witch

<table>
<thead>
<tr>
<th>CR</th>
<th>Importance</th>
<th>Sharpen edges</th>
<th>Axe</th>
<th>Ditch Witch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trench specs</td>
<td>2</td>
<td>0.3</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Labor time</td>
<td>1</td>
<td>0.2</td>
<td>0.6</td>
<td>1</td>
</tr>
<tr>
<td>Satisfactions</td>
<td></td>
<td>1.8</td>
<td>2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Ditch Witch is the clear choice because of its performance, even when restrained by its high cost. This results from the high importance of performance, and lower importance of cost. The project team might want to adjust for a higher cost importance, if appropriate.