Important Note: We must split up these exams for grading. Therefore:

- If you need more space for a problem, continue it on an additional sheet, clearly identify the problem number on the additional sheet, write your name on the additional sheet, and slip it behind the first page of the continued problem. (Additional sheets are available from the instructor, or feel free to supply your own.)

- Put your name on every page and every attached page.

We are not responsible for points lost due to pages having no name nor problems being continued in difficult to find places (such as the back side of a different problem).

- Open Books, Open Notes.

- Please show all work to enable assignment of partial credit.

- Any questions? Please ask!

1. The injection molded manifold covers that we are designing for the NO$\nu$A neutrino detector are nominally 1175 mm long, 80 mm wide and 135 mm high. The wall thickness is a uniform 3 mm. The material is rigid PVC. The maximum injection pressure is approximately 120 MPa, and the melt temperature is 205°C.

What is the minimum machine capacity required to mold this part? (5 pts)
2. Multiple choice questions (2 pts each):
   Note: Each question has only one answer.

   (a) What would be the best resin to use for plastic countertops (which may come in contact
       with hot pots and pans)?
       i. ABS.
       ii. Melamine.
       iii. Nylon.
       iv. Polycarbonate.

   (b) What property is a plastic likely to exhibit if it has a low glass transition temperature?
       i. It may creep significantly under load.
       ii. It will have a low melt temperature.
       iii. It will have a low tensile modulus.
       iv. It will have a low tensile strength.

   (c) What is the most likely manufacturing process used to form hexagonal heads on bolts?
       i. Blanking.
       ii. Casting.
       iii. Machining.
       iv. Upsetting.

   (d) What is likely the lowest cost manufacturing option for parts with large surface areas
       (for example, the cases of air conditioners)?
       i. Casting.
       ii. Injection molding.
       iii. Machining.
       iv. Shearing, piercing and press brake forming.

   (e) Why are rolled threads considered to be superior to machined threads?
       i. They cost less to manufacture in high volumes.
       ii. They can be made faster.
       iii. They are stronger.
       iv. All of the above.
       v. None of the above.

   (f) What is likely the best manufacturing option for fabricating 50 identical parts which
       require high precision and significant detail?
       i. Closed die forging.
       ii. Injection molding.
       iii. Machining.
       iv. Sheet metal forming.
3. The leg of a standard staple has a width of 0.46 mm, a depth of 0.52 mm and a length of 5.9 mm. Assume the staple is made of a steel with properties similar to AISI 1015 as-rolled steel.

Estimate the magnitude of the compressive force which will cause each leg to buckle. (18 pts)
4. The return spring for a push button is illustrated below. The spring acts as a cantilever beam-type spring. The effective length is 50 mm. The spring is 10 mm wide and 0.5 mm thick. The spring is fastened to a frame with a #4-40 machine screw. The hole diameter for the screw is 3 mm.

The applied force, $F$, is zero when the button is up and 2.3 N when the button is down.

The spring is fabricated from I:AISI 1095 spring steel, oil quenched and tempered at 540°C (1000°F). The stock material is cold rolled prior to heat treatment.

Estimate the working life that 99% of the springs will reach in number of cycles. (30 pts)
5. An industrial rolling mill is equipped with 750 mm diameter rolls. The mill is used to process a billet of pure annealed copper which has an initial length of 1 m, an initial width of 0.5 m, and an initial thickness of 25 mm.

(a) The billet is reduced in thickness from 25 mm to 22.5 mm on the first pass. Estimate the force applied to the rolls during this pass. (11 pts)

(b) The billet is reduced in thickness from 22.5 mm to 20 mm on the second pass. Estimate the force applied to the rolls during this pass. (5 pts)

(c) How long is the 20 mm thick sheet? (2 pts)

(d) What is the yield strength of the 20 mm thick sheet? (2 pts)

Please make the above estimates using the frictionless rolling model.
6. The NOνA neutrino detector requires 12,000 15.5 m long PVC extrusions whose cross-
sectional shape is indicated below. Ten sample extrusions are randomly pulled from each 
batch of 100 extrusions that are cut, and their width is measured. The sample data which 
has been compiled after taking five such samples of ten parts is included in the table below. 
(Note that the average width in each sample has been pre-computed for you.)

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<th>sample 3</th>
<th>sample 4</th>
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</table>

| x̄ s        | 655.14   | 655.16   | 655.19   | 655.16   | 655.23   |

(a) Compute the values of the upper control and lower control limits for the plots of the 
average width and range of widths based on the data gained after 5 samples. (13 pts)

(b) Assume the plots of the average width and the range of widths appear as shown below
after 20 samples have been taken. Suggest what may be happening during the extrusion 
process based on these plots. (2 pts)