Notes: A few final exam questions may be taken from this assignment.
There will be various components (bearings, gears, etc.) on outside SH110 later – I will let you know when. But I highly encourage you to visit them.

1) (5 pts) In this class, we are moving into "component" design. We will not be going into great depth regarding specific component design, but is meant to be an overview of each component – learning enough to know what you don't know. Shaft design includes determining ways to transfer torque into or out of the shaft (for example, "keys" and "key ways"), as well as concerns about off-balance spinning introducing undesired vibrations. Towards that end, watch the videos on shafts linked here and at the bottom of the course web page. To receive credit for this problem, you must watch the video and write a brief one sentence description of what each video is about:
   Shafts:
   a) (2 min) https://www.youtube.com/watch?v=RxHLy294b2g
   b) (4.5min) https://www.youtube.com/watch?v=ZRbOux9NfeU
   c) (1 min) http://www.youtube.com/watch?v=WAujhNP5uvU
   d) (2.6 min) http://www.youtube.com/watch?v=gmV4qwLfOMY
   e) (0.5 min) https://www.youtube.com/watch?v=vfLLaDsGWk0

2) *(5 pts) Educational Purpose: mechanical engineers design and select "stuff" to solve problems. Your mind needs to experience the physical world through your senses – much more than looking at photographs or online resources. This assignment allows your senses to contribute to your brain growth.* Near the plow test facility, there are items relevant to this assignment. Visit this to play with the "self-helping" break apparatus (it looks a lot like the sketch in problem 3 – the tire NEEDS cleaned from time to time otherwise it is very slippery). Try to compress the spring (which looks a lot like a spring in problem 4). Identify bearing seals and identify unique characteristic of the various bearings. For credit on this problem, state "I looked at and operated all of the relevant items."

3) (5 pts) Background information: Many braking systems are to some extent either "self-helping" or "anti-self-helping" in the sense that the braking force produced can exceed or be less than the force input to the system, respectively. In an extreme case, self-helping can actually become self-locking ("infinite" braking force may be applied without any external force – like a doorstop).

This homework question incorporates (combines) three different design topics: self-help design, brake design, and "fail safe" design. You are working for a winch manufacturer (if you don't know what a winch is, you know how to figure out what it is). It is desired to have a winch that has a braking mechanism to prevent the load from dropping should input power be lost (hence, it is "fail safe").   The winch shown below lifts a load by rotating the drum clockwise. No external force is applied to the brake mechanism, other than its own weight which keeps the brake pad in contact with the drum. The weight of the mechanism is

unknown (and is not important for this problem – neglect it). Dimension "b" is 100mm and dimension "c" is 300mm.

Determine the minimum coefficient of friction required for this braking system to be "self-locking" for counterclockwise rotation. Hint: although it may not look like it, when the drum rotates counterclockwise, this system produces "wedging" forces similar to a doorstop. Therefore, the more torque you apply to try to cause counterclockwise rotation, the greater the braking force becomes to oppose it. To solve this problem, take the sum of moments about the pivot point (of course, include FBD). Two forces will be included in that summation: the normal and friction forces between the drum and the brake. For static equilibrium, the moments they produce about the pivot point must sum to zero.
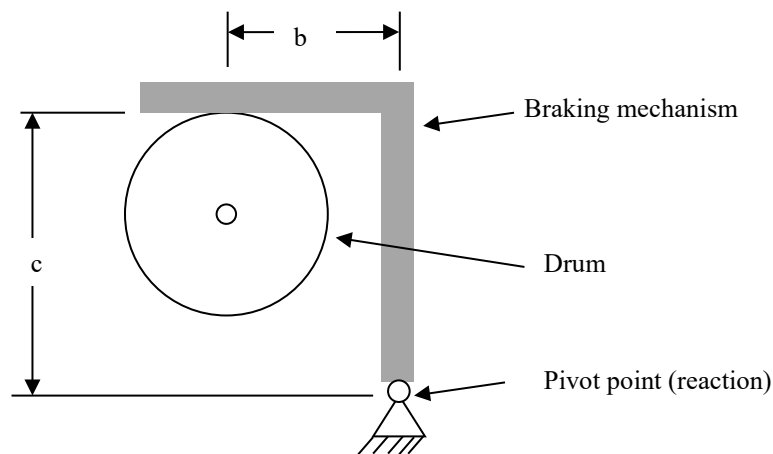
4) (5 pts) a) What is spring surge and what conditions cause it? b) how is spring surge detrimental to performance?; c) Very briefly describe how coil springs are made. Watch the following videos:
 *(5 min) How spring are made:* https://www.youtube.com/watch?v=WeU89tdq55c
  (1.5 min)Valve spring surge (float): http://www.youtube.com/watch?v=yfmb-tCo2yA

Engineers are not experts in everything. Bearing manufacturers have engineering representatives that are experts in bearing design and application. If you need to select a bearing for a design, utilize the experts. But you need to have a working knowledge of a few terms…

5) (5 pts) Use sketches and/or words to define/describe the following with respect to their meaning or purpose with **regards to bearings**: axial load, radial load, bore diameter, outer diameter, speed, lubrication, sealing (keeping "dirt" out, and lube in), preload.

6) (5 pts) For a 20mm bore, single row 02 series deep groove ball bearing, find the radial load that can be carried for an L_D life of 5000 hours at 900 rpm. Assume bearing manufacturer uses L_{10} of 10^6 revolutions.

7) (5 pts) Describe what is qualitatively wrong with the following design (no analysis required – something is conceptually very wrong). There are two pulleys, one on each end. The shaft (shown as gray in the sketch) transmits torque from one pulley to the other. There are two ball bearings supporting the shaft. There are two shoulders machined into the shaft to position the pulleys and the bearings. Keys are used to transfer load from the pulleys to the shaft and visa versa. Rings and groves are used to hold the bearings against the shoulders and nuts are used to hold the pulleys against the shoulders (not shown). The nuts are held in place with cotter pins. Hint, if pictures are worth a 1000 words, then a physical mockup is worth 1000X1000 words as the Hyatt Regency walkway revealed.
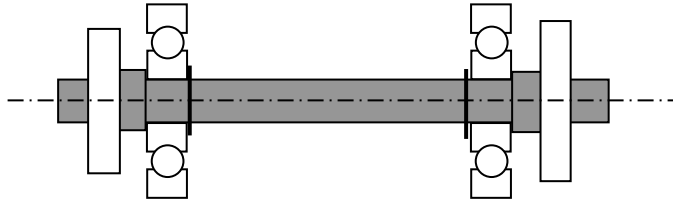
Now onto gears…one of the quintessential components of mechanical engineering. You should google any terms that are not familiar to you.

8) (5 pts) For a pinion with 10 teeth and a pitch diameter of 3 inches, what is the diametral pitch (teeth per inch)? If the pinion as described in the previous sentence, is supplying power to the gear, and the torque output is to be twice the input (speed is reduced by a factor of 2), define the driven gear – how many teeth does it have, what is its pitch diameter, what is its diametral pitch?

9) (5 pts) Name the following types of gears (they are on display in SH120)

    (a)   (b)   (c)   (d)

10) (7 pts) To answer the following questions, use internet search and/or the video links on the course web page and/or the course textbook.
   a) Why are helical gears used forward motion in automotive transmissions?
   b) Why are spur gears used for reverse motion in automotive transmissions?
   c) What is a synchronizer?
   d) Why do cars have differentials (what's their function)?
   e) What is a torque converted and how do they function?
   f) Why does the brake master cylinder have two pistons? Hint: think "fail safe"
   g) How do anti-lock braking systems work?

11) (5 pts) For the following acronyms – **who** invented these and **when,** and **what** does the acronym stand for: LASER, RADAR, SCUBA, SONAR … and that completes Machine Design homework forever and ever!

Congratulations! You have survived your junior year in mechanical engineering at the Donald P. Shiley School of Engineering (well, getting close at least….)!…but….to help you ease off of your addiction to school work, the following links may prove interesting. If you watch them all, it will take about 45 minutes. These are totally up to you to watch or not. Please let me know if there are any dead links. If you find any additional links that others may appreciate, please let me know.

Transmissions:
How a manual automotive transmission works (6 min):
https://www.youtube.com/watch?v=wCu9W9xNwtI
Torque Converters (4.5 min):
https://www.youtube.com/watch?v=z5G2zQ_3xTc

Bearings:
(6 min) Tapered roller bearings installation:
https://www.youtube.com/watch?v=JugU6NHgqVY
 (5 min)– Making of ball bearings http://www.youtube.com/watch?v=b6svVy1lYOA
(1 min) - hydrodynamic journal bearing https://www.youtube.com/watch?v=GwBj27hwypI

Gears:
(5min) How Gears are made: http://www.youtube.com/watch?v=XZgsV0AZJJ0
(5 min) How an automatic xmission works: https://www.youtube.com/watch?v=Ugao6jTyM7k
 (1.5 min) What is a differential:
http://www.youtube.com/watch?v=29QpZrMQ9v8&feature=related
(3 min) Torque converter: http://www.youtube.com/watch?v=MvLoX0z9qoY&NR=1
(5 min) "Out of the box" gears: http://www.youtube.com/watch?v=WYcqJ5HdxA4

Wire Rope:
(5 min) Steel rope, how it's made: http://www.youtube.com/watch?v=eDVf71xd2cQ

Braking:
(2 min) Braking system: http://www.youtube.com/watch?v=bMg_j5_AGMg
(6.7 min) Antilock Braking System (ABS):
https://www.youtube.com/watch?v=98DXe3uKwfc

Summer time watching – a very interesting story about development of the first re-usable spaceship developed without government support. Notice the creativity the engineers demonstrate since they do not have significant testing resources (it is over an hour long, so get comfortable).
Black Sky, The Race for Space & Wining the X-Prize: https://vimeo.com/111120337