Donald P. Shiley School of Engineering
ME328 – Machine Design
Spring 2019, Assignment 11

SOLUTIONS ARE EMBEDDED WITH SOME OF THE QUESTIONS

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

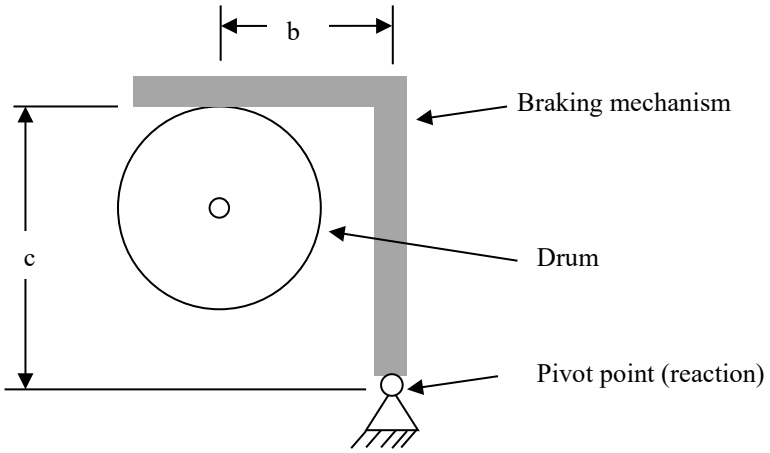
2) *(5 pts) Educational Purpose: mechanical engineers design and select "stuff" to solve problems. Your mind needs to experience the physical world through your senses – much more than looking at photographs or online resources. This assignment allows your senses to contribute to your brain growth.* 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.



(SOLUTION IS ATTACHED – Separate file)

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

a) spring surge is caused by very rapid extension/compression of the spring creating a wave-like motion in the spring.

b) the spring force will not be linear with displacement, and in fact in extreme conditions the spring my loose contact with what it is supposed to be pushing on.

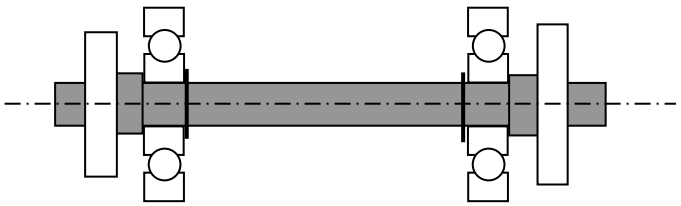
Engineers are not experts in everything. Bearing manufacturers have engineering representatives that are experts in bearing design and application. If you need to select a bearing for a design, utilize the experts. But you need to have a working knowledge of a few terms…

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.

axial load: force applied in the direction of the shaft's axis
radial load: force acting radially (perpendicular to shaft's axis)
bore diameter: inside diameter of the bearing
outer diameter: outside diameter of the bearing
speed: how fast it go roundy-roundy (revolutions per minute)
lubrication: grease or similar is used to reduce corrosion and wear
sealing (keeping "dirt" out, and lube in): keeps dirt or other contaminates out and or lubrication in
preload: on tapered roller bearing, there needs to be a slight axial load to keep the bearing together

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. *SOLUTION IS ATTACHED – Separate file*

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. SOLTUION: it is not possible to put the bearings where they are positioned – there is no way to get them "over" the shoulders.



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? *SOLUTION IS ATTACHED – Separate file*

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

(a)
Spiral bevel

(b)
Cross-helical

(c)
Straight Bevel

(d)
Spur

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?
They have smooth tooth-to-tooth engagement and therefore are quieter than spur gears.

b) Why are spur gears used for reverse motion in automotive transmissions?
They are easily slid in and out for gear-to-gear engagement (and disengagement), but are more expensive than helical gears. Since a car is not driven for extended periods in reverse (hopefully), the noise they produce is not troublesome.

c) What is a synchronizer?
The synchronizer helps match the speeds of gears before engaging. This helps the two gears engage without grinding.

d) Why do cars have differentials (what's their function)?
Differential gear sets allow power transmission to both left and right sides of the vehicle, yet allow for different rotation rates encountered during cornering.

e) What is a torque converted and how do they function?
Torque converters transfer power smoothly from internal combustion engines using fluid. When output speed is lower than input speed, torque is increased. They allow for internal combustion engines to continue to run while the vehicle in not in motion.

f) Why does the master cylinder have two pistons? Hint: think "fail safe"
In case one of the brake lines fails (fractures, leaks) half of the vehicle's brakes will still work.

g) How do anti-lock braking systems work?
Sensors on the brake determine if the wheel stops rotating. Before rotations is stopped, the brake pressure is released allowing the wheel to continue to spin. This prevents the brakes form "locking" the wheels which would result in skidding (and hence, loss of control) and decreased friction ($\mu_{dynamic} < \mu_{static}$).

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….)!